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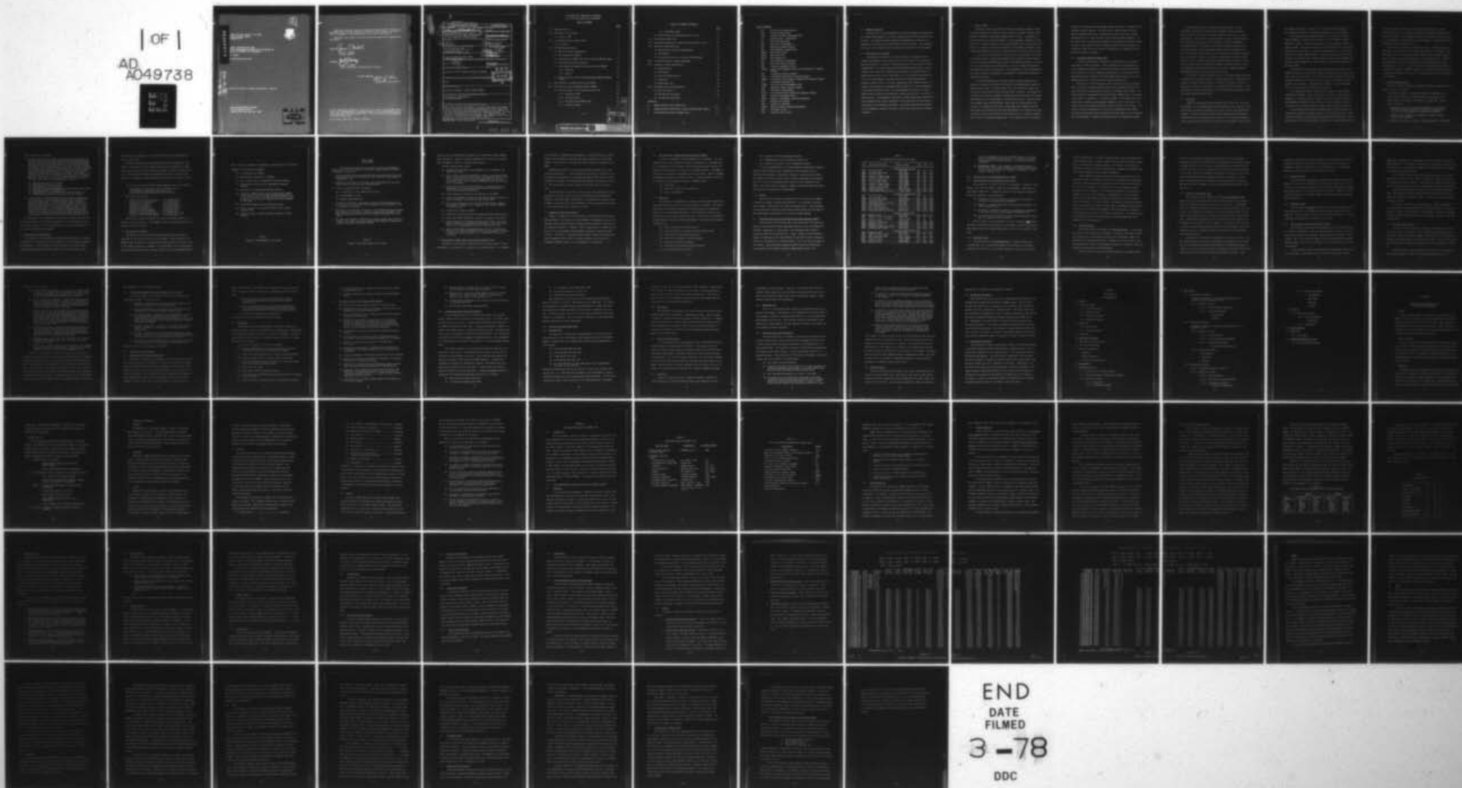

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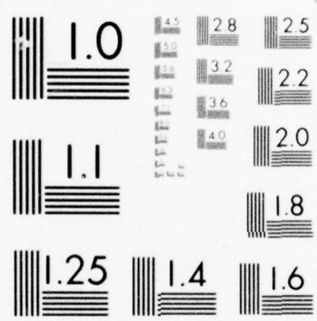

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RADC-TR-77-376, Volume II (of two)
Final Technical Report
December 1977

IEMCAP IMPLEMENTATION STUDY
Annex Electromagnetic Compatibility Handbook for System Development and Procurement

E. Freeman

Sachs/Freeman Associates

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ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
Griffiss Air Force Base, New York 13441

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This volume contains an EMC handbook to be used by both the Air Force System Project Offices and by their prime or integrating contractors to aid them in applying computerized intrasystem analysis techniques to their program. The Air Force Intrasystem Analysis Program (IAP) is discussed in detail. Both the SPO's EMC responsibilities and the contractor's EMC responsibilities are addressed. The EMC Program Plan is outlined. Also, guidance is given on the organization and operation of the EMC Advisory Board.

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ELECTROMAGNETIC COMPATIBILITY HANDBOOK

FOR SYSTEM DEVELOPMENT AND PROCUREMENT

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

List of Acronyms

ASD:	Aeronautical Systems Division
CDR:	Critical Design Review
CDRL:	Contract Documents Requirement List
C-E:	Communications - Electronics
DID:	Data Item Description
ECM:	Electronic Countermeasures
ECP:	Engineering Change Proposal
EMC:	Electromagnetic Compatibility
EMCAB:	EMC Advisory Board
EMCCP:	EMC Control Plan
EMCPP:	EMC Program Plan
EMI:	Electromagnetic Interference
ESD:	Electronic Systems Division
FMO:	Frequency Management Office
GEMACS:	General Electromagnetic Model for the Analysis of Complex Systems
IAP:	Intrasystem Analysis Program
ICAP:	Intrasystem Compatibility Analysis Program
IEMCAP:	Intrasystem Electromagnetic Compatibility Analysis Program
ISF:	Intrasystem Signature File
LCSMM:	Life Cycle System Management Model
NCAP:	Nonlinear Circuit Analysis Program
PDR:	Preliminary Design Review
PSTAT:	Precipitation Static Electricity Analysis Program
RADC:	Rome Air Development Center
RDT&E:	Research, Development, Test and Evaluation
RFP:	Request for Proposal
RFQ:	Request for Quotation
SAMSO:	Space and Missile Systems Organization
SOW:	Statement of Work
SPO:	Systems Project Office

1.0 Handbook Objective

The objective of the EMC Handbook for System Development and Procurement is to present EMC guidance to Air Force Systems Project Offices and their contractors. The handbook presents technical and management procedures to be employed for the promotion of better EMC in Air Force systems. The breadth of the subject matter requires that the subject be covered in a succinct manner.

2.0 EMC and Air Force Systems

Electromagnetic systems are the nerve centers of a majority of the systems and equipments that enable the Air Force to perform its various missions and functions. Successful development and use of such systems involves consideration of the often complex interface between diverse factors (such as monetary costs, available technology and manpower), and a dynamic range of present and potential service requirements. For those systems requiring the use of the electromagnetic frequency spectrum for surveillance/sensing, telemetry, weapon control or the more conventional radio communications circuitry, the availability of adequate spectrum support is a firm prerequisite to successful system operation. The electromagnetic spectrum is a finite resource that is shared by military and civilian users in the U. S. and foreign countries. Electromagnetic Compatibility (EMC) aspects must therefore be given appropriate and timely consideration (in conjunction with other major influences) in the planning, development, procurement and operational phases of electromagnetic systems if they are to effectively perform their intended functions.

2.1 Levels of EMC

The range of EMC considerations includes the question of where to place a specific junction on a chassis as well as whether a specific frequency band should be assigned to land mobile communications or radar. It pervades all levels and phases of system development. At the component, chassis or circuit level it is a primary concern of the circuit designer and is largely under his control. At higher levels where integration of subsystems and systems is performed, EMC assurance requires the cooperative efforts of many diverse groups.

It is in the best interests of the Air Force to assure that, to the maximum extent possible, systems and equipments will be able to perform compatibly in all planned configurations and will have maximum flexibility to be used in as yet unforeseen future configurations. The role of EMC specifications and standards includes this objective. Full dependence on such techniques can be costly in terms of overdesign at one extreme or in deficient protection of systems at the other.

At the most preliminary or initial levels of system fabrication the designer or builder has sufficient motivation in preventing EMI in order to make his device work. At higher levels (e.g., the "black box" level), the objectives of the builder and the user may begin to diverge. The builder has an item that functions according to performance specifications and also meets EMC standards, e.g., MIL-STD-461A. His objectives are met. Since the black box standards (such as MIL-STD-461A) cannot take all configurations into account, the integration contractor or user agency that assembles sets of black boxes into systems may still have EMC problems. The controls over this situation include the provisions of MIL-E-6051D which is a mandatory requirement to assure intrasystem compatibility. This standard relies on extensive

testing of the subsystems and equipments against each other to demonstrate EM compatible system operation. The complexity of modern systems and their numerous operating modes (e.g., adaptive array radars, EMC pods, multiple configurations, etc.) make the use of such testing extremely expensive. In many cases there is limited time scheduled for performing MIL-E-6051D testing. In order to meet these restrictive schedules and still assure adequate consideration of EMC, the use of analytical capabilities to highlight areas of possible problems is required.

3.0 Intrasystem Analysis Program (IAP)

A reliable and efficient procedure for assuring EMC is a necessary technique for quality assurance. Such a procedure can be accomplished by valid mathematical modeling of the system and reduced testing requirements. The availability of such a capability also allows for the tailoring of EMC specifications and the prediction of EMC conditions that might occur due to granting waivers or deviations from the specification limits.

Recognition of this situation by the Air Force has led to the development of a group of computer programs known as the Intrasystem Analysis Program (IAP) under the sponsorship of Rome Air Development Center (RADC). The IAP includes the Intrasystem EMC Analysis Program (IEMCAP) which is discussed in more detail in Appendix C. In addition, models for the EM effects on aircraft stores, lightning, magnetospheric substorms, static electricity, nonlinear circuits and systems and EM near fields are part of the package. The office of primary responsibility for the IAP is Headquarters AFSC (SDDE). The Rome Air Development Center Compatibility Branch (RBC) is the lead agency for the development of IEMCAP and the majority of the supplementary models.

Intrasystem EMC concerns the EM compatibility within a system consisting of electrically interconnected equipments and/or equipments located within or on an entity such as an aircraft, spacecraft, or ground installation. The next level, intersystem EMC, concerns the EMC situation between systems, vehicles and other components of the electromagnetic environment beyond the confines of the proximal grouping described above. The characteristics of the intersystem problem include a predominance of antenna-to-antenna coupled energy in the far-field and operational solutions based on distance separations, frequency assignment and time and frequency sharing. This is a dynamic situation requiring constant attention. Assistance in dealing with the intersystem problem is available through the DoD Electromagnetic Compatibility Analysis Center (ECAC), command frequency assignment agencies, and various private contractors.

As a result of factors discussed above, the Systems Project Office EMC responsibility is largely focused at the intrasystem level. Capabilities are required to assess the EMC situation, determine the effects of waivers or deviations, and tailor specification or standard limits as required. Other supplementary related capabilities are also required and are included in the Intrasystem Analysis Program (IAP).

3.1 IAP Codes

IEMCAP is the primary computer program (code) in the IAP. This code was designed to perform EMC specification generation, waiver analysis, baseline design, and trade-off analysis for aircraft, ground, and space/missile systems. The code is based on military specifications of electromagnetic (EM) emitting and receiving ports of a system. The four major EM coupling modes considered are wire-to-wire, case-to-case, environmental field-to-wire,

and antenna-to-antenna. The code is built in ANSI Standard FORTRAN IV. A more detailed description is contained in Appendix B of this handbook.

The Generalized Electromagnetic Model for the Analysis of Complex Systems (GEMACS) is another code in the IAP. It is a computer program designed to support a variety of techniques for electromagnetic analysis of complex systems. The current version of the code supports all the functions necessary for the analysis of a wire grid representation of a system using the Method of Moments (MOM) technique. The user may obtain the electrical currents, far-and near-field radiation patterns, antenna input impedance and antenna coupling parameters for wire antennas on structures represented by wire grid models.

The Precipitation Static Electricity Analysis Program (PSTAT) is an engineer-designed, first generation computer program that will predict equivalent noise fields and short circuit antenna currents produced by corona and streamer discharges in an airborne avionics system. The computer code is divided into two models. One performs the analysis for corona discharge while the other performs a streamer noise analysis.

The lightning phenomena is modeled by two computer codes entitled APERTURE and DIFFUSION. These codes assist their users in predicting the magnitudes of lightning induced voltages in aircraft electrical circuits. The APERTURE and DIFFUSION codes calculate the field intensity within an aircraft (due to coupling) through an aperture and diffusion in the skin.

The Nonlinear Circuit Analysis Program (NCAP) allows an engineer to determine the nonlinear transfer functions of an electronic circuit. NCAP solves the nonlinear network problem by premultiplying a generator vector by the inverse of the first-order nodal vector matrix. These elements are the

first order transfer functions at all nodes in the network at a given excitation frequency. For higher order transfer functions a repetitious procedure is utilized. These nonlinear transfer functions are directly related to such phenomena as intermodulation, cross modulation, desensitization, gain compression, spurious responses, etc.

These codes all operate in a "stand alone" mode. The PSTAT and lightning models can interface with the IEMCAP code through one of IEMCAP's input data parameters. The other codes can be utilized after an IEMCAP analysis to assess a potential interference problem at a more detailed level. Additions and modifications to IAP in these and other areas (including an advanced lightning model, a model to predict the effect of magnetospheric substorms on space/missile systems, a TEMPEST capability, electroexplosive devices, electroexplosive subsystems, etc.) will be a continuing effort under the guidance of the RADC/RBC.

4.0 SPO EMC Responsibilities

AFR 80-23, USAF Electromagnetic Compatibility Analysis Program (Para.14) reads, in part, as follows:

"The AFSC will carry out a program of research, development, test and evaluation (RDT&E) to evolve techniques, circuits, and components which are designed, from concept, to acheive EMC. Specifically, AFSC will:

a. Emphasize EMC in the design and development of electrical and electronic equipment (see AFR 57-1, AFR 80-2, and AFR 800-2 for policy on the management of design and development).

b. Emphasize EMC in RDT&E of C-E tedhniques, component design, circuits, and equipment."

In addition, AFSCP 800-3, A Guide for Program Management, (Paragraph

8-21) contains the following:

"a. With the advent of more complex electronics and an increase in the quantity and diversity of electronic components being designed into Air Force equipment, additional emphasis is being placed on designing EMC into electronic systems early in the conceptual and validation phases of the system acquisition life cycle. AFR 80-23 assigns the responsibility for EMC to 'each organization and each person that participates in managing the acquisition and use of this equipment..' This is an awesome responsibility for a program office design engineer and can become very expensive when EMC is not achieved and retrofits are required. To assist the design engineer in achieving EMC, AFSC established several focal points for EMC in the product divisions, test centers, and laboratories. They are:

(1) ADTC/DLJA-EMC applied to armament;
(2) AFFDL/FGL-Lightning protection;
(3) AFWL/SECM-EMC for nuclear safety;
(4) ASD/ENAMA-Development engineering and application of EMC Design;
(5) ESD/DRT-System EMC and TEMPEST R&D;
(6) RADC/RBC-Exploratory development in all facets of EMC; and
(7) SAMSO/DRU-EMC technology as applied to missile systems.

b. A major task of the EMC engineer is to ensure that a thorough and concise EMC plan is prepared identifying the EMC requirements for the system under design. Another important aspect of the EMC engineer's responsibility is tailoring the military standards and specifications to meet specific system design objectives. These include considerations of technical requirements, types of equipment, system mission cost, and schedule. Adjusting the military standards and specifications to achieve the most effective EMC for a system is an extremely difficult task for which the EMC engineer should request assistance from the focal points identified above."

The requirement for a thorough and concise plan is a good starting point for the fulfillment of the SPO EMC responsibility. The development of that plan and the inclusion of the IAP requirements in it are discussed below. It is titled an EMC Program Plan (EMCPP).

4.1 EMC Contractual Documentation

The foundation for establishing an appropriate EMC program for a systems acquisition is a thorough, specific and complete set of contractual documents. The categories of these documents include the Request for Proposal (RFP), Contract Documents Requirements List (CDRL), Data Item Description (DID),

Specifications and Standards. The SPO EMC office has a responsibility in each of these areas.

The RFP or RFQ should include EMC provisions in the Statement of Work (SOW). The evaluation factors summary should include consideration of EMC, preferably with some significant associated number of points or weighting factors. The CDRL should include the requirements for data, IAP outputs and analysis. An example of a CDRL addendum for this purpose is shown in Figure 1.

The Data Item Descriptions (DID's) most commonly called out for EMC are:

Electromagnetic Compatibility Plan DI-R-3530/S-116-1;
Electromagnetic Compatibility Test Plan; and
Systems and Subsystems/Equipment DI-T-3704/T704-2.

EMC related DIDs include:

Category II Test Plan Procedures	DI-T-3706/T-106-2;
General Test Plan Procedures	DI-T-3707/T-107-2;
Test Reports - General	DI-T-3718/T-119-2;
Category II Test Reports	DI-T-3719/T-120-2;
Acceptance Test Reports	DI-T-3721/T-125-2;
Engineering Change Proposals	DI-E-3128/C-141-1;
Request for Deviation/Waiver	DI-E-3129/C-142;
Subsystem Design Analysis Report	DI-S-3581/S-101-1; and
Category I Test Plans/Procedures	DI-T-3702/T-102-2.

These can be modified as desired by the use of DID Back-up Sheets. An example is shown in Figure 2. This example concerns desired specifics in the EMC Control Plan (DI-R-3530).

4.2 EMC Program Plan (EMCPP)

The EMCPP is the SPO's planning document delineating the process by which EMC for the specific project will be achieved. Major elements of the EMCPP include procedures for achieving EMC during each phase of the life cycle of the system, subsystem or equipment, the establishment of the interrelationships and reporting procedures of those involved in the program regarding EMC

Note: This is an example of an addendum to the CDRL list for IAP items.

"Submittal to include the following:

(1) the input data for IEMCAP;

(2) description of input data for IEMCAP;

(3) copy of input data for supplemental modeling analysis;

(4) description of input data for supplemental modeling; analysis

(5) description of supplemental modeling analysis;

(6) analysis of IEMCAP output data and supplemental modeling output data (to reflect the most current configuration at at the delivery date) to be delivered 180 CD after contract go-ahead, at CDR, and final delivery 30 CD after delivery of end items;

(7) intra-system signature file delivery per item 6;

(8) items 1 through 4 to be delivered 180 CD after contract go-ahead; and

(9) changes to items 1 through 4 shall be submitted for SPO approval."

Figure 1

Example of CDRL Addendum for IAP Items

BACK-UP SHEET
DI-R-3530/M

The Preparation Instructions of basic DI-R-3530, Electromagnetic Compatibility Plan are modified to include the minimum updated information requirements listed below.

4. Work accomplished and results obtained during the report period for each task defined by the work statement and the contractor's Electromagnetic Compatibility Plan.

5. Summaries of the status of previously reported problems that were unresolved at the close of the last reporting period.

6. A list of current problems containing:

   (a) A description of the problem and its effect.

   (b) Accomplishment to date.

   (c) Expected resolution date.

7. A specific accounting of each design review action item remaining open at the end of the last report period including a full description of the action taken on each item.

8. Discussion of the progress and status of the Intrasystem Analysis Program when applied on the contract. Results, problem areas, marginal performance and design actions indicated by the Analysis Program shall be reported.

9. The final Electromagnetic Compatibility Program Progress Report shall be a summary type report indicating the major electromagnetic compatibility problems encountered and results achieved.

Figure 2

Example of DID Back-Up Sheet for IAP Items

matters, and the establishment and support of an EMC Advisory Board (EMCAB) where appropriate. Whenever necessary throughout the life cycle of the program, the EMCPP is subject to updating and revision.

The EMC program manager should:

(a) consider EMC requirements from standpoint of the equipment, subsystem and system;

(b) plan for EMC (including programming of funds for any specific EMC task) in each stage of the life cycle, and integrate the use of the IAP in all phases; assure that the minimum number of runs (i.e., for the EMC Control Plan, at PDR, intermediate point, CDR and Test Plan) are included;

(c) insure that the external EM environment is considered during the development of the procurement specifications (including any required EMC intersystem analysis);

(d) insure appropriate preparation and updating of the EMCPP;

(e) make intrasystem EMC a contractual requirement through inclusion in contract documents, especially the CDRL and the SOW;

(f) assure that the general use of the IAP and EMC receives adequate considerations (weight) in the evaluation of contractor response to the RFQ or RFP;

(g) establish and support an EMCAB;

(h) establish and maintain liaison with appropriate EMC support groups;

(i) insure that timely application is made for frequency allocations;

(j) insure preparation of comprehensive EMC Control Plans, Test Plans and Test Reports and guarantee the availability of the latest IAP results for the appropriate decision or review points; and

(k) assure that the EMC data base supporting IAP (e.g., Intrasystem Signature File (ISF) from IEMCAP or other IAP components) is properly stored and updated and that it is a deliverable item from the contractor.

4.3 Relationship of EMCPP, EMC Control Plan and EMC Test Plan

The EMCPP is a SPO document, initiated at the earliest stages of system development or procurement at the option of the program manager. Its emphasis

is on the policy, philosophy and management of the EMC program to be implemented, and the analysis techniques and general guidance for the SPO EMC manager. The SPO policy on the IAP utilization should be contained in the EMCPP.

The EMC Control Plan is a contractor-developed document that is very technical and specific. It should emphasize what specific techniques are to be applied to precise parts of the system and should define when such applications are to be made. The utilization and results of IAP should be included. The control plan is usually required 60-120 days after the contract award.

The EMC Test Plan is written by the contractor and delineates the implementation of the tests called for in the specifications and standards as applied to the system under consideration. The detailed test procedures are included. The use of IAP in the development of the test plan and the results of such usage should also be taken into account.

4.4 Frequency Allocation Procedures

Chapter 5 of AFM 100-31 contains guidance concerning the allocation and EMC procedures to be employed in system planning. Development of any new C-E equipment family using the radio frequency spectrum requires an "Application for Frequency Allocation" (DD1494). AFSC is responsible for submitting this form for all C-E equipments being developed, procured, or used by an AFSC activity. The DD1494 is submitted through command channels to the USAF Frequency Management Office (FMO) for initial frequency allocation and for upgrading equipment status, e.g., developmental to operational.

4.5 Electromagnetic Compatibility Advisory Board (EMCAB)

The SPO is responsible for the organization of the EMCAB. It is the responsibility of the organizer to assure the preparation of the EMCAB charter, availability of the necessary clerical and administrative support and assure the effectiveness of the board in its assigned mission. The EMCAB is tailored for the particular equipment, system or platform. Smaller equipment development programs do not normally require a formalized EMCAB. Factors to be considered in determining the need for an EMCAB include:

(a) system cost;

(b) importance of EMC for the system; and

(c) project organization.

4.5.1 Objective

The objective of the EMCAB is to assist in resolving EMC problems that arise during the life cycle of a platform, system or equipment. This assistance shall be provided by advising the concerned parties of appropriate methods for correcting EMC deficiencies. The "objective" section of the EMCAB Charter should clearly define this point. The steps to be performed in accomplishing the objective should be delineated. These steps shall include such details as:

(a) review of EMC Control and Test Plans;

(b) group discussions to discover potential problem areas;

(c) examination of potential problem areas;

(d) review of the progress of the EMC program;

(e) definition of specific problems;

(f) determination of possible problem solutions;

(g) review of EMC Waiver requests;

(h) selection of the most desirable solution;

(i) recommendations to the performing activity; and

(j) review of the results of the recommended solutions.

It is the responsibility of the Electromagnetic Compatibility Advisory Board to perform studies, make recommendations and otherwise assist in achieving electromagnetic compatibility between the end product and similar and dissimilar electrical and electronic systems, subsystems, and equipments. The use of the IAP in performing these studies should be mandated by the EMCAB. The board should be composed of members qualified to make appropriate decisions and recommendations on EMC problems.

4.5.2 Charter

Since the charter forms the framework of all functions of the EMCAB, it should be complete, accurate and definitive. In an attempt to maintain such precision, some steps in the charter may appear basic. These seemingly trivial points will prevent the board from becoming ineffective and unable to make appreciable contributions to the solution of EMC problems.

4.6 Waiver/Deviation Actions and Engineering Change Proposals (ECP's)

The procuring activity should take action and process the requests for waivers in accordance with their departmental EMC directives (including MIL-STD-480), regulations, or instructions. The appropriate DID's should be invoked and modified as described in 4.1 above. Usually the most difficult aspects to determine are the "side-effects" of the waiver and the cumulative effects of a multiplicity of approved waivers. Use of the IAP will assist in this regard. Waiver/deviation requests and ECP's should be substantiated with appropriate IAP analysis results for EMC-related actions. The

TABLE I

TRI-SERVICE EMI MIL-STD-461A/462 TESTS

Test	Test Identification	Frequency Range	Army	Navy	A.F.
		CONDUCTED EMISSION (CE)			
CE01	DC Power Leads	30Hz-50Hz	Yes	No	No
CE01	AC & DC Power Leads	30Hz-20kHz	NA	Yes	Yes
CE02	AC Power Leads	10kHz-50kHz	Yes	No	No
CE02	Control & Signal Leads	30Hz-20kHz	NA	Yes	Yes
CE03	Control & Signal Leads	30Hz-50kHz	Yes	NA	NA
CE03	AC & DC Power Leads	20kHz-50MHz	NA	Yes	Yes
CE04	AC & DC Power Leads	50kHz-50MHz	Yes	NA	NA
CE04	Control & Signal Leads	20kHz-50MHz	NA	Yes	Yes
CE05	Control & Signal Leads	50kHz-50MHz	Yes	NA	NA
CE05	Inverse Filter Method	30Hz-50MHz	NA	Yes	NA
CE06	Antenna Terminal	10kHz-12.4GHz	Yes	Yes	Yes
CE07	Power Source Tactical Veh.	1.5MHz-65MHz	Yes	NA	NA
		CONDUCTED SUSCEPTIBILITY (CS)			
CS01	DC Power Leads	30Hz-50kHz	Yes	No	No
CS01	AC & DC Power Leads	30Hz-50kHz	No	Yes	Yes
CS02	AC & DC Power Leads	50kHz-400MHz	Yes	Yes	Yes
CS03	Intermodulation	30Hz-10Hz	Yes	Yes	Yes
CS04	Rejection Undes Sig (2 Gen)	30Hz-10Hz	Yes	Yes	Yes
CS05	Cross-Modulation	30Hz-10GHz	NA	Yes	Yes
CS06	AC & DC Power Leads	Spike Gen.	Yes	Yes	Yes
CS07	Atn. Input-Squelch Cir.	Impulse Gen.	Yes	Yes	Yes
CS08	Rejection Undes Sig (1 Gen)	30Hz-10GHz	NA	Yes	Yes
		RADIATED EMISSION (RE)			
RE01	Magnetic Field	30Hz-30kHz	Yes	Yes	No
RE02	Electric Field, Broadband	14kHz-1GHz	Yes	No	No
RE02.1	Electric Field, Narrowband	14kHz-12.4GHz	Yes	No	No
RE02	Electric Field	14kHz-10GHz	No	Yes	Yes
RE03	Spurious & Harmonics	10kHz-40GHz	Yes	Yes	Yes
RE04	Magnetic Field	20Hz-50kHz	Yes	Yes	Yes
RE05	Vehicles & Eng-Driven Equip.	150kHz-1GHz	Yes	Yes	Yes
RE06	Overhead Power Lines	14kHz-1GHz	Yes	Yes	Yes
		RADIATED SUSCEPTIBILITY (RS)			
RS01	Magnetic Field	30Hz-30kHz	Yes	Yes	No
RS02	Induction Field Spike	Spike Only	Yes	No	No
RS02	Mag. Induction Field	Power & Spike	NA	Yes	Yes
RS03	Electric Field	10kHz-400MHz	Yes	No	No
RS03	Electric Field	14kHz-10GHz	No	Yes	Yes
RS04	Electric Field	14kHz-30MHz	No	Yes	Yes

as well as management controls for an EMC program. It incorporates parts of MIL-E-6051D, MIL-STD-461, and MIL-STD-462, with numerous additions and modifications. It includes an analysis requirement.

(g) MIL-STD-1542 (USAF): This standard is a companion document to MIL-STD-1541, the standard encompasses EMC and grounding requirements for basic facilities and equipment (including air conditioning, lighting, etc.).

6.0 The Life Cycle System Management Model (LCSMM)

6.1 The Five Phases of the Acquisition Life Cycle

The acquisition life cycle consists of five phases: conceptual, validation, full-scale development, production and deployment. This regime is described in AFSCP 800-3. Significant aspects of this process are specific DoD policy guidelines. Among these are:

(a) flexibility in the selection of the strategy or technique to be used for any given system development;

(b) emphasis on hardware development during concept formulation to reduce technical risks;

(c) incremental independent development of subsystem and components in the initial stages of major system developments; and

(d) the introduction of multiple decision points during the development and acquisition of new systems.

The five phases of the acquisition life cycle represent a formalized procedure not always fully utilized for all programs. Specific programs may skip phases and various program elements may be in any or all phases at any time.

6.1.1 Conceptual Phase

The first phase is the Conceptual Phase. Technical military and economic bases for an acquisition program are established in this phase. Included are definitions of operational capability, doctrine, and specific

material requirements. Performance characteristics may be established only in very general terms. Critical technical and operational issues are identified for resolution in subsequent phases. The outputs of this phase are alternative concepts and their characteristics, estimated operational schedules, and procurement costs and support parameters.

These planning documents provide the first opportunity for the consideration of EMC. Preliminary selection of the frequency band, modulation and other principle technical characteristics of the system are required in the case of C-E equipment. An application for an experimental frequency allocation is also required. For systems and equipments not specifically designed to utilize the RF spectrum, a determination of system technical characteristics is needed to evaluate and establish controls on potential mutual interference. The EMC activities are primarily concerned with determining the occupancy of frequency bands, required bandwidths, application of appropriate specifications and standards, and in developing an estimate of EMC feasibility as an input to the first decision point. The organization of an EMC Advisory Board and the development of an EMC Program Plan may be desirable for certain projects.

6.1.2 Validation Phase

The second phase of the LCSMM is the Validation Phase. In this phase the choice of the alternative is validated. Frequently this phase includes the construction of prototypes to refine costs, environmental impact, and operational and technological factors. Extensive study and analysis, hardware development, testing, and evaluation is devoted to providing a basis for decisions concerning full-scale development.

EMC activities in this phase include preparation of the EMC-related

portions of the equipment performance specifications for the prototypes, development of plans for the EMC portion of development and operational tests, reviewing results of the EMC testing, and verifying that potential EMC problems have been averted or can be expected to be resolved during later phases. At this point frequency and bandwidth requirements are usually in final form, requiring application for a developmental frequency allocation. At this stage an appropriate analysis capability could be applied to tailoring the EMC specifications or standards to provide appropriate EMC protection at the least cost.

6.1.3 Full-Scale Development Phase

The third phase in the LCSMM is the Full-Scale Development Phase. During this period the system and principle items necessary for its support are fully developed and engineered, fabricated, and tested. The intended output is a minimum pre-production system that closely approximates the final product, the documentation necessary to enter the production phase, and test results that demonstrate that the production system will meet stated requirements. Engineering development contracts are awarded and the second set of development and operational tests is conducted. The program office activity is heavily oriented towards design reviews and the test program. The initial production contract is awarded following the completion of the development and operational tests.

The products of this phase are subjected to a third set of tests. The EMC considerations and actions in this phase include preparation of the EMC part of the equipment development specifications (including generating the limits for the tailored specifications), preparation of the EMC tests for the second and third test series, and review of the EMC test results. Also

included are verification that EMC performance of developmental and initial production equipment is satisfactory and verification that the system or equipment is ready for production from an EMC viewpoint. The operational spectrum allocation application is prepared at this time.

6.1.4 Production Phase

The fourth phase, Production, encompasses the program from production approval to delivery and acceptance of the last item. EMC activity is concerned with the production specifications, configuration management, engineering change proposals, and system and equipment testing. Category II and III testing is monitored to determine whether latent intrasystem or intersystem EMC problems exist.

6.1.5 Deployment Phase

The fifth phase, Deployment, begins with the user's acceptance of the first operational unit and extends until the system is phased out of the inventory. There is usually an overlap with the production phase. At times, production and deployment are discussed as one phase.

6.2 EMC Procedures and Responsibilities by Phase

The discussion above should be recognized as a rather idealized model of a system's acquisition. There are many differences with the real world process that complicate EMC analysis, testing and fix requirements. Nevertheless, even for the idealized LCSMM, definite EMC procedures and responsibilities emerge. Each of the five phases in the acquisition life cycle has such specifics.

In the Conceptual Phase the preliminary system/equipment characteristics are defined. This definition can be based on specification limits,

design data, analogies (e.g., measurements of similar systems), simulation and/or modeling. In this phase, applications for experimental frequency allocations are made. This requires frequency band selection and the collection of equipment characteristics data.

The Validation Phase is where the EMC specifications are developed. MIL-STD-461, MIL-STD-1541, MIL-I-6181, MIL-E-6051 and others may be used or the specifications may be tailored. This phase also includes an EMC evaluation of prototypes and applications for developmental frequency allocations.

Specification development is handled in the Full-Scale Development Phase. EMC characteristics are analyzed and verified and an application for operational frequency allocations is made. At this point, plans for initial production are made.

The phases of Production and Deployment have similar requirements. It is in these phases that modifications are analyzed and tested. All follow-up action and retrofit are also handled in these phases. Frequency assignment actions, taken when difficulties occur in the program, are also a major part of these phases.

7.0 The Industrial EMC Cycle

The view of the EMC engineer or analyst at the industry level is not usually as broad or long-term as the above LCSMM description might imply. One reason is that an individual company or EMC group will not necessarily be involved in the same project over the entire time span. Seen from this level, the work will also be assigned as separate tasks with no gurantee of continuity.

The EMC process at this level task is a cycle that may be repeated many times throughout the LCSMM. The following subparagraphs are an

explanation of the procedure.

(a) Review customer requirements. The request for quotation (RFQ) or request for proposal (RFP) is the usual first input. The operational requirements and specifications are analyzed and an EMC program approach and requirements are defined.

(b) Define contractual commitments. Clarify and amend specifications, and determine customer, contractor, and subcontractor obligations and commitments. Then assure data interface and analytical capability, perform trade-offs, negotiate requirements, and finally, establish a schedule.

(c) Prepare Control Plan. Perform EMC frequency and time domain analysis based on system configuration and mission analysis definitions. Define problems and methodology to provide solutions possibly by establishing system/subsystem requirements for design, control and test. Refine the schedule and define an EMC program for the system and each subsystem in enough detail so as to serve as a management tool for monitoring and controlling the EMC effort.

(d) Implement EMC Program. Ensure that the analysis, design test and documentation effort defined in the Control Plan is performed as required. Prepare and update data base and take appropriate actions to assure EMC as the program progresses by implementation of the methodology established.

(e) Subsystem tests. First, write test procedures, then validate marginal designs/design trade-offs. The final step will be qualification testing.

(f) System tests. Develop and prosecute system tests, then validate system and subsystem compatibilities. Follow-up by evaluating problems, verifying solutions, and documenting results.

Therefore, the procedure, as far as the contractor is concerned, is primarily one of analyzing and verifying EMC conditions within his system in the particular phase in which he is currently involved and taking preventative or corrective action as appropriate. The IAP should be extremely valuable in this activity. The particular portions of the EMC cycle performed, he accuracy requirements, data inputs, and required outputs are a function of the particular life cycle phase. For example, while the use of tailored EMC specifications might not be appropriate in the validation phase, they may be

very appropriate for the production phase.

8.0 Intrasystem Compatibility Analysis Program (ICAP) Facility

In order to support the Air Force IAP, a facility (ICAP) has been established at RADC. Its functions are:

(a) Education. Short courses for engineers, systems analysts and management personnel are regularly presented.

(b) Update and Maintenance. Performance of all modifications and maintenance of the computer programs comprising IAP.

(c) Limited EMC Support. Assistance in the application of the IAP for eligible Air Force and contractor organizations. This support includes assistance in writing statements of work, attendance at preliminary and critical design reviews, and equipment and system test support.

(d) New Model Integration. Integration of new models into the IAP package, including the development of necessary supporting documentation.

(e) Data Base. Maintenance of system data bases developed through the use of the IAP. This will assure the economical availability of data as the system progresses through its life cycle.

(f) User Group Liaison and Coordination. Distribution of literature, user group experiences, lessons learned, code changes, etc.

The prime contact for this activity is RADC/RBC.

9.0 Contractor Responsibilities

9.1 Specification Compliance Requirements

Subsystems, equipments and components should be designed and constructed so their individual electromagnetic interference emission and susceptibility characteristics comply with the requirements of the version of MIL-STD-461 in effect at the time of system procurement or as tailored for the specific procurement. Where appropriate, radar subsystems and equipments should additionally comply with the requirements of the version of MIL-STD-469 in effect at the time of system procurement. Deviations to the

limits of MIL-STD-461 or MIL-STD-469 are considered by the Air Force only under circumstances where the contractor can demonstrate that such deviations

(a) will not prevent the system from achieving its Technical Performance Characteristics as defined in the General Specification;

(b) will not degrade the Technical Performance Characteristics or exceed the Performance Thresholds of any other systems being procured as defined in the General Specification; and

(c) represent good engineering design practice.

All deviations should be accompanied by an IAP analysis.

9.2 EMC Program

Contractors, whether performing under a production, development or definition contract, have the responsibility of establishing and implementing the necessary EMC program to meet the contractual requirements. Guidelines or directives for the contractor to present in order to fulfill his responsibilities are as follows:

(a) include his approach to EMC in his proposal;

(b) prepare an EMC Control Plan in accordance with contractual requirements including an IAP analysis and results;

(c) prepare EMC design guidelines for contractor design personnel;

(d) validate equipment needs for specific EMC requirements;

(e) prepare EMC design guidance and evaluation, utilize EMC checklists for assurance of proper design;

(f) prepare EMC test plans;

(g) perform EMC testing and document results;

(h) provide necessary information to procuring activity for frequency allocations data;

(i) prepare necessary integration with other engineering programs;

(j) perform EMC analysis on a systems basis using the IAP package as appropriate; and

(k) implement subsystem and equipment emission and susceptibility control.

9.3 Evaluation Criteria for Contractor EMC Programs

The contractor EMC program should include the following items:

(a) responsibility and authority of the person who will direct and implement the contractor's EMC program;

(b) number and experience of full-time and part-time EMC personnel available for the program;

(c) methods and requirements for ensuring that the contractor-developed subsystems and equipments will not be adversely affected by interference sources within the system and that sources of interference that might adversely affect the operation of the other systems are properly considered;

(d) identification of gross problem areas and proposed methods of solution;

(e) identification of the process by which compliance with the interference control specifications/standards will be assured;

(f) details of participation and support of the EMC Board activities;

(g) discussion of significance of identification and methods of complying with the margins identified by the procuring agency in the RFP;

(h) frequency management considerations and spectrum control methods;

(i) discussion of the data requirements for support of the approach and methods of acquiring these data;

(j) discussion of waiver/deviation and Engineering Change Proposal (ECP) analysis procedures and methods for implementation;

(k) management chart showing how EMC information flows from subcontractor to integrating contractor, as well as within the integrating contractor's shop, i.e., between the EMC functional organization and the project;

(l) identification of all EMC milestones against the background of the project schedule;

(m) identification of all CDRL items, an outline of their content, and an indication of their delivery schedule;

(n) identification of specific control methods relative to subcontractors, i.e., their critical documents, review methods, delivery date, content, review meetings, etc.;

(o) utilization and scheduling of IAP analysis including application to the areas above; and

(p) IAP data base development and availability.

10.0 Intrasystem Analysis Program Scheduling

As was discussed earlier, the contractor EMC effort on a specific project usually starts at the time of the proposal effort. On typical large projects (such as an aircraft or large weapons system) the data required to run IEMCAP is available at that time. It is quite reasonable, therefore, to require that IEMCAP be used to develop the EMC Control Plan. The EMC Control Plan is also a requirement of MIL-STD-461 and MIL-E-6051D. Data Item Description (DID) DI-R-3530/M, Electromagnetic Compatibility Plan, can be augmented by a back-up sheet (as was shown in Paragraph 4.1) to include IEMCAP requirements.

The initial submission of the Control Plan should be about 90 to 120 days after contract award. The contractor will be free to use the IAP as required in the performance of his work. Up-to-date IAP input/output data should be available at PDR, CDR and for EMCAB meetings. It should also accompany any requests for deviations or waivers. MIL-E-6051D test plans should also be based partly on IAP results. These results and analyses should be included in the plan submitted. A suggested minimum schedule for running IAP and compiling and analyzing the output is as follows:

(a) when writing the EMC Control Plan;

(b) at Preliminary Design Review (PDR);

(c) at a convenient point between PDR & CDR;

(d) at Critical Design Review (CDR); and

(e) when writing the System Test Plan.

Upon completion of the contract the IAP input/output and data base shall be delivered to the SPO. This should also be a CDRL item. This should be accompanied by a summary wrap-up report describing the results and important experiences obtained throughout the EMC process as applied to the project. The SPO will assure that a copy of this data is delivered to the ICAP facility for safekeeping. This is a crucial requirement for the intrasystem analysis process and should be emphasized.

11.0 Contractor Testing Requirements

11.1 Responsibility

The contractor is responsible for performance of all tests and procedures required for the verifications of EMC compliance and for EMC analysis support. Specifically, this responsibility shall include implementation of the following:

(a) an Inter-System EMC Test Plan;

(b) an Intra-System EMC Test Plan;

(c) a MIL-STD-461 Test Plan;

(d) a MIL-STD-469 Test Plan; and

(e) any other EMC tests or test plans that are to be implemented as a part of this contract.

Except as otherwise specified in the contract or order, the contractor may use his own or any other facilities suitable for the performance of tests or verification procedures (unless disapproved by the government). The Air Force reserves the right to have one or more of its representatives in attendance

during all or part of any tests that relate to EMC compliance. The Air Force also reserves the right to perform any of the tests or verification procedures set forth in this or any other related specification. This will be done where such tests are deemed necessary to assure that products and services conform to the prescribed requirements.

11.2 EMC Testing

EMC validation or compliance tests may be conducted concurrently with product qualification, acceptance, or demonstration tests. This is allowed providing no test detracts from the quality, validity, usability, or completeness of any other test. Partial design verification of EMC characteristics may be demonstrated by laboratory tests, tests of prototype equipment, or analytical processes in accordance with the planning and analysis requirements of this specification.

11.3 Test Plan Modifications

It is recognized that the requirements of both intersystem and intrasystem testing may change during the contract. Such changes may be the result of hardware design changes, conclusions reached from intersystem and intrasystem EMC Studies, measurement results from tests already performed, or other causes. The contractor shall periodically (at least every 3 months) review the Test Plans and make additions, deletions and modifications to the plans. This will insure the plans' conformity with the current needs of the system. The results of such review will be a subject of EMCAB proceedings.

11.4 Retesting

Failure of a particular test to indicate equipment, subsystem or system compliance to given specification limits shall immediately invoke

requirements on the contractor. These are: to re-enact that test after remedial design changes have been introduced and again perform other tests whose results might be altered due to these system design changes. These measures should satisfy the requirements.

11.5 Maintenance Log

A log is to be maintained that indicates the malfunctions that occur during a test program. Malfunctions to be considered include those either to the equipment, subsystem, or system being tested or to test instrumentation being employed for the test. This log shall include a description of the malfunction, at what point in the test program it occurred or was noted, and what remedial steps were necessary.

12.0 Contractor Reporting Requirements

The prime contractor, in conjunction with any other required contractors and subcontractors, should prepare reports throughout the life of the contract that describe the progress being made in the performance of the System EMC Studies. This should be included as a CDRL item with appropriate DID references and back-up sheets. A typical requirement would be for quarterly reports. These reports will be reviewed by the EMCAB. They should contain, but not be limited to, the following:

(a) the results of any IAP analyses;

(b) a detailed discussion of the status of the study, including the technical approaches being employed, the accomplishments made, and the future study plans in those analysis areas;

(c) test requirements generated as a result of the study;

(d) a discussion of all potential and actual EMC problem areas uncovered by the study (including interference to the subject system from another system), interference to another system from the subject system, and interference between two or more

subject systems (problem areas that are identified by EMC Tests shall be included in this discussion);

(e) a discussion of those EMC problem areas that will be resolved by engineering changes to the system, including explanations of the changes;

(f) a discussion of any recommended changes to other systems that would resolve EMC problem areas (an identification of why this method of problem resolution is preferable to one which involves only modification to the system being procured will be included);

(g) a discussion of those EMC problem areas that cannot be resolved except by the undesired solution of placing some limitation on operating parameters of that system or some other system (such as operating frequency limitations, separation distance limitations, time-sharing limitations, antenna pointing angle limitations, etc.), (indications of why the problem area cannot be resolved any other way should also be included); and

(h) identification of EMC problem areas that have not yet been resolved (including a discussion of the seriousness of the unresolved problem areas) and indications of the approaches being considered or taken for resolving the problems shall be included.

As an example, a quarterly report is due to the Procuring Activity within 20 calendar days after the quarterly period. Each report shall be subject to approval by the procuring activity. Approval of the report does not imply authorization of any changes to the contract of the system being procured. For cases covered by paragraphs (e) and (f) above, the government can request and the contractor shall implement specific supplemental studies. The studies will offer the potential of engineering changes to the system being procured in an attempt to resolve those cases.

12.1 EMC Test Reports

The prime contractor should submit a test report, which describes the results of the System EMC Tests. The format of this report, which will be presented within 60 calendar days after completion of the tests, shall be as specified in MIL-STD-831. The test reports should be a CDRL item with the

appropriate DID reference as contained in 4.1 above.

12.2 MIL-STD-461 Test Report

A MIL-STD-461 test report on each test sample should be prepared by the organization performing the MIL-STD-461 compliance tests. The test report for each test sample shall be submitted to the procuring activity within 60 calendar days after completion of compliance tests. The report should also meet the content requirements for such a document as specified in MIL-STD-461 and should be submitted through the channels indicated by the EMC Control lan. Supplements to the MIL-STD-461 Test Report should be provided when retesting is necessary. The report is considered accepted by the procuring activity unless notification to the contrary is made within 60 calendar days after receipt of the report, or unless the government advises the contractor that a specific additional amount of time will be taken to review the report.

12.3 MIL-STD-469 Test Report

A MIL-STD-469 test report describing the results of the tests performed to determine compliance with MIL-STD-469 shall be prepared by the contractor(s) after completion of the compliance tests. The test report shall meet MIL-STD-469 requirements. The report shall be submitted to the procuring activity for approval through the channels indicated by the EMC Control Plan within 60 calendar days after completion of the tests. Supplements to the MIL-STD-469 Test Report shall be provided when retesting is necessary. The report should be considered acdepted by the procuring activity unless notification to the contrary is made within 60 calendar days after receipt of the report, or unless the government advises the contractor that a specific accitional amount of time will be taken to review the report.

APPENDIX A

SAMPLE OUTLINE
OF
EMC PROGRAM PLAN

1.0 <u>General</u>

1.1 Scope and Purpose

1.1.1 System Description

1.1.2 Purpose of Plan

1.1.3 Time Period Covered

1.1.4 Updating Provisions

1.2 Background

1.2.1 Prior Effort

1.2.2 Historical Summary

1.3 Definitions

2.0 <u>Applicable Documents</u>

2.1 Standards and Specifications

2.2 Data Item Descriptions

2.3 Special Documentation

- Handbooks
- Guidance Documents
- Technical Data and Reports

3.0 <u>Requirements</u>

3.1 Management Approach

3.1.1 Organizations and Codes Involved

3.1.2 Interrelationships and Reporting Procedure

3.1.3 EMC Advisory Board

3.1.3.1 Membership

3.1.3.2 Operating Procedures

3.2 EMC Analysis

3.2.1 Environmental Analysis

(Interactions between the system and environment due to systems on other platforms or sites)

3.2.1.1 Methods to be Used

3.2.1.1.1 EMC Environment Definition

3.2.1.1.2 Output Requirements

- Documentation
- Schedule

3.2.2 Intersystem Analysis

(Interaction between the system and other systems on same platform or site)

3.2.2.1 Methods to be Used

3.2.2.1.1 Specific Models

3.2.2.1.2 Data Sources and Requirements

3.2.2.1.3 Organizations Tasked

- Contractor Responsibilities

3.2.2.2 Output Requirements

- Documentation
- CDRL Items
- Schedule

3.2.3 Intrasystem Analysis

3.2.3.1 Interactions within the system

3.2.3.2 Methods to be Used

3.2.3.2.1 IAP Utilization

3.2.3.2.2 Data Sources and Requirements

3.2.3.2.3 Organizations Tasked

- Contractor Requirements

3.2.3.2 Output Requirements

- Documentation
- CDRL Items
- Data Base
- Schedule

3.3 EMC Tests

3.3.1 Specification Tests

3.3.1.1 Data Requirements

- CDRL Items

3.3.1.2 Scheduling

4.0 Master Schedule

4.1 Milestones

4.1.1 Task Outputs

5.0 Funding Requirements by Task

5.1.1 FY Quarterly Requirements

APPENDIX B

ORGANIZATION AND OPERATION OF THE EMC ADVISORY BOARD (EMCAB)

1. CHARTER

Since the charter forms the framework of all functions of the EMCAB, it should be complete, accurate and definitive, otherwise the board will be ineffective and will not be able to make appreciable contributions to the solution of EMC problems. Where a contractor is involved it should be prepared by the contractor and submitted to the Procuring Activity with the EMC Program Plan.

2. AREA OF INTEREST

The area of interest of the EMCAB should be described in detail in the Charter. This necessitates a description of the system, subsystem, or equipment under procurement that may cause EMC problems or be susceptible to EMI. A description of EMI responsibilities to be assigned within the contractor and subcontractor organizations should also be included.

3. MEMBERSHIP

The EMCAB Charter should completely specify the board membership identified by organization, board position, and job title, and should probide for non-members to attend meetings, if these non-members are required in the discussion of an agenda item. The membership should consist of representatives of the Procuring Activity and of appropriate

contractors. Secretarial, documentation, clerical and other administrative support services required by the EMCAB would normally be provided by the contractor.

4. RESPONSIBILITIES

All board responsibilities should be delineated in the EMCAB Charter. The EMCAB shall serve in an advisory capacity to the Systems Project Office, contractor or subcontractors in regards to any EMC problem that receives the attention of the board. Individual board member responsibilities should include the following items:

a. Chairman- Chair all meetings

Approve agenda, meeting dates and other EMCAB documents

Assure timely EMCAB action on EMC problems

b. Vice Chairman - Serve as chairman in the chairman's absence

Plan, organize and implement meetings

Provide for the preparation of agenda, summary reports and minutes of the meetings

c. Member - Provide interface between the EMCAB and his organization

Present EMC problems to the board

Participate in problem solving

Report EMCAB problem solutions to his organization

Report company action on EMCAB recommendations

d. Secretary - General and special secretarial duties as required

5. OPERATION OF THE EMCAB

6. AUTHORITY

The EMCAB acts in an advisory capacity to assist in resolving EMC problems that may arise. It should participate in scheduled system EMC design reviews at specific points in the system development cycle and generate recommendations for the solution or further definition of the problem areas uncovered. These reviews should be supported by the most current IAP data.

7. SCHEDULING

Scheduling of EMCAB functions should be included in the Charter, and the schedule should be relative to the date of contract award. The first board meeting should be held within 60 days of approval of the Charter, and the interval between EMC design reviews established by the Charter should be implemented. These reviews should be held at least quarterly unless a shorter interval is desirable. The established interval can be supplemented by special meetings called by the chairman if requested and justified by any member.

8. AGENDA

Agenda shall be prepared by, or under the supervision of the vice-chairman in advance of each regular or special meeting. The chairman of the EMCAB shall be responsible for the content, preparation and distribution of all agenda. The preparation should be according to his direction and the content s ould be approved by him before reproduction for distribution. The preparation should be sufficiently in advance to permit distribution to the EMCAB members

so that it may be received at least 15 days prior to the meeting. This will permit each member to review the agenda and enclosures,and determine the official position of his company or activity on each item to be covered in the ensuing meeting. Reproduction facilities and associated expenses should be the responsibility of the contractor whether owned facilities or purchased services are utilized.

9. MEETINGS

Meetings should be held at the intervals and locations specified in the board charter, unless specific circumstances warrant a change. In general, these intervals should not exceed three months with the first meeting held within 60 days after Charter approval. The meetings should be specifically defined as to meeting times and locations, with provisions for special meetings when required. Meeting locations should be defined in the Charter for all meetings throughout the life of the EMCAB. These locations can be at the contractor's location, on a rotational basis among the contractor and subcontractors, or on whatever basis is convenient for the members, with consideration being given to the nature of the anticipated EMC problems.

The meetings shall proceed in a manner that is consistent from meeting to meeting. The following items and order of items is recommended but deviations, additions and omissions may be made if such change improves the effectiveness of the meetings.

(a) Registration................................Secretary

(b) Call to Order - Announcements, Introductions....Chairman

(c) Welcome addresses as required...................Chairman

(d) Reading and discussion of minutes...............Secretary

(e) Old business....................................Secretary

(f) Member reports..................................Members

(g) New business....................................Chairman

(h) New business....................................Members

(i) Preparation of board plans......................Chairman

(j) Tentative next meeting plans....................Chairman
(agenda topics, place and date)

(k) Summary of Conference...........................Chairman

(l) Adjournment.....................................Chairman

Attendance at a meeting is contingent upon proof of a clearance equal to the highest security category to be discussed in the meeting and a need to know. Registration for all attendees shall consist of recording the full name, security clearance, board position, sponsoring organization, position in the sponsoring organization, and duration of attendance if that duration is less than the length of the board meeting.

10. PROBLEM

In general, EMCAB action shall be based upon individual and collective reviews of anticipated and current contractual functions. These reviews will reveal potential EMC problems. From this basic information flow, the board shall recognize balid problems that will fall within the advisory capacity of the board. These procedures lead

to the selection of problems that shall be acted upon by the EMCAB. Part of this problem selection consists of assigning the time sequence of the board activities. This time sequence shall consider the urgency of each problem, and the difficulty that may be encountered in evolving a solution to be recommended by the board.

Some of the factors to be considered in determining the time schedule for resolving a problem shall be as follows:

(a) the time schedule of the program in which the problem is encountered or expected;

(b) the amount of background search that will be necessary to establish a firm basis for understanding the problem;

(c) the amount of technical research that will be necessary to establish the technical parameters and data that will form the framework for the various possible solutions;

(d) the amount of modeling, fabrication, and testing that will be required to assure a successful operation of the recommended solution;

(e) the time and effort required to generate adequate reports of tests, investigations, and conferences to make a complete record upon which the board can evaluate the possible problem solutions;

(f) the probability of conflicting viewpoints among the board members, whether these conflicts are from technical approaches, or from administrative circumstances;

(g) the cost that would be encountered in the application of each reasonable solution to the problem;

(h) the degree of relaxation of a requirement that would be feasible for each particular problem;

(i) delays that may be encountered in the use of regular or special meetings of the board to evaluate progress on each problem. This must include effort directed toward other and unrelated problems.

APPENDIX C

THE INTRASYSTEM ANALYSIS PROGRAM (IAP)

1.0 INTRODUCTION

The IAP presently comprises a series of independent but related technical components which are being developed under separate contracts by the organizations and sponsoring Air Force Project offices listed in Table C-1. The overall effort is officially named the "Intrasystem Analysis Program" (IAP). Rome Air Development Center (RADC) is the lead agency for development of the IEMCAP, development of the supplemental model on aircraft stores, integration of all supplemental models, and the nonlinear and EM/near-field analyses. The Air Force Intrasystem Electromagnetic Working Group, chaired by AFSC (SDDE), was established early in the progrma to prepare the requirements and plans for use of the IAP. Agencies represented are shown in Table C-2. The major component of this collection of computer codes is the Intrasystem EMC Analysis Program (IEMCAP). This program is described in more detail below.

2.0 THE INTRASYSTEM EM COMPATIBILITY ANALYSIS PROGRAM (IEMCAP)

2.1 Objective

The Intrasystem Electromagnetic Compatibility Analysis Program (IEMCAP) was designed to provide an effective and cost beneficial means of EMC analysis throughout the stages of an Air Force system's life cycle from conceptual studies of new systems to field modification of old systems. Ground, aircraft, and space/missile systems are within the IEMCAP capability. The program is relatively computer independent and has been implemented on CDC,

TABLE C-1

INTRASYSTEM ANALYSIS PROGRAM (IAP)

ANALYSIS MODEL	ORGANIZATION	AF PROJECT OFFICE
° INTRASYSTEM EMC ANALYSIS PROGRAM (IEMCAP)	MCDONNELL ACFT CO	RADC
° SUPPLEMENTAL ANALYSIS MODELS		
° ELECTROEXPLOSIVE DEVICES	LOS ALAMOS SC LAB	ASD
° ELECTROEXPLOSIVE SUBSYSTEMS	SANDIA CORP	ASD
° LIGHTNING	GENERAL ELEC CO	FDL, NASA
° STATIC ELECTRICITY	STANFORD RSRCH INST	ASD, SAMSO
° TEMPEST	TRW SYSTEMS GP	ESD, SAMSO
° AIRCRAFT STORES	(IN-HOUSE PROJECT)	RADC
° SPACECRAFT CHARGING	(IN-HOUSE PROJECT)	AFGL, SAMSO
° NONLINEAR CIRCUIT ANALYSIS	SIGNATRON INC	RADC
° EM FIELDS ANALYSIS	RADC, SYRACUSE U. BDM	RADC
° ADVANCED COMPOSITE MATERIALS	NOTRE DAME U., ROCHESTER INST. OF TECH., U. OF S. FL.	RADC

TABLE C-2

AFSC INTRASYSTEM ELECTROMAGNETIC WORKING GROUP

ORGANIZATION	SYMBOL
° AIR FORCE SYSTEMS COMMAND (CHAIRMAN)	SDDE
° ROME AIR DEVELOPMENT CENTER (LEAD TECHNICAL AGENCY)	RBC
° AERONAUTICAL SYSTEMS DIVISION	ENAEA
° SPACE & MISSILE SYSTEMS ORGANIZATION	AWS
° ELECTRONIC SYSTEMS DIVISION	DR
° AIR FORCE FLIGHT DYNAMICS LABORATORY	FES
° ARMAMENT DEVELOPMENT & TEST CENTER	DCJA
° AIR FORCE WEAPONS LABORATORY	SECM
° WARNER ROBINS AIR LOGISTIC CENTER	MMEEI
° OKLAHOMA CITY AIR LOGISTIC CENTER	MMSHA
° SACRAMENTO AIR LOGISTIC CENTER	MMEWH
° AIR FORCE COMMUNICATIONS SERVICE	EIUM
° ELECTROMAGNETIC COMPATIBILITY ANALYSIS CENTER	ACL
° RAND CORPORATION	
° AEROSPACE CORPORATION	

Honeywell, IBM, Univac and Xerox computers. It is programmed in USA standard FORTRAN IV language and requires approximately 70K words of core.

IEMCAP analysis demonstrates the relationship between equipment and subsystem EMC performance and total system EMC characteristics in specific terms. It therefore provides the means for tailoring EMC requirements to the specific system. This is accomplished by modeling the system elements and the mechanisms of electromagnetic energy transfer to accomplish the following tasks:

a. provide a data base that can be continually maintained and updated to follow system design changes;

b. generate EMC specification limits tailored to a specific system;

c. evaluate the impact of granting waivers to the specifications;

d. survey a system for incompatibilities;

e. analyze the effect of design changes on system EMC; and

f. provide comparative analysis results on which to base EMC trade-offs decisions.

2.2 Data Organization

The data base that supports the IEMCAP analysis is a hierarchical structure relating the system, subsystem and equipment levels of system organization. For example, a Ground Controlled Approach (GCA) system would be composed of radar, communications, computer and display subsystems which are, in turn, composed of "black boxes", or equipments, consisting of transmitters, receivers, antennas, control units, multicouplers, etc. The devices through which the EM energy is transferred in and out of these equipments are designated "ports". These ports may be intentional or unintentional. For example, an equipment case with poor shielding integrity is an unintentional

port, whereas a power cable that exits an equipment is an intentional port.

2.3 Analysis Approach

Intentional ports, have intended functions to perform. The operationally required signals or responses associated with these functions are intentionally generated and cannot be altered without affecting system operation. In addition to these required signals, undesired operationally non-required outputs and/or responses may exist. Examples of operationally non-required signals include harmonics and spurious emissions or spurious responses.

An EM incompatibility is determined to exist when an interfering signal from an emitter port, or ports, is coupled to a receptor port through any path, and is large enough to exceed the susceptibility threshold. The limits for non-required signals are defined in EMC specifications. An important task of IEMCAP is the generation of a set of specification limits tailored to the specific system under analysis.

The emissions and susceptibilities, both required and non-requred, are represented in IEMCAP by spectra (frequency versus amplitude characterizations). For each emitter port, a two-component (broadband and narrowband) spectrum represents the power levels produced over the frequency range. The broadband component consists of noiselike or largely unintentional emissions, that are fairly constant over wide frequency ranges whereas the narrowband component is usually well defined within a limited frequency range. The broadband components are in units of power spectral density. The narrowband components are in units of power.

For each receptor, a spectrum represents its susceptibility threshold

versus frequency characteristic. This susceptibility standard threshold is the level of minimum recieved signal which produces a standard response at a given frequency.

A frequency range is defined as the required range for each intentional port. Signals within this range are those required for operation, and therefore not adjustable for EMC purposes. Outside this range specified limits may be established for the maximum emission and minimum susceptibility levels. The spectrum within the required range can be defined by a mathematical model. This is done by using the theoretical equations of the frequency domain representation of the signal, or may be input as a user-defined spectrum.

The specification generation process adjust these assumed spectrum levels to achieve compatibility if interference is indicated. By readjusting the spectra of emitters and receptors the maximum non-required emission and minimum susceptibility levels are obtained for a compatible system. To prevent overly stringent specifications from being generated, each spectrum has an adjustment limit.

In order to initiate the process, IEMCAP uses the limits of military EMC specifications MIL-STD-461A and MIL-I-6181D or a modification thereof. The user has the option of adjusting these at his discretion. These specifications are involved because of their wide application at the equipment level and most EMC engineers are familiar with them. This philosophy also helps to assure that, if new equipments are added to a system containing existing equipment developed and tested to these specifications, the IEMCAP-generated specifications will be at the same general levels and not result in radical changes in EMC design. It also facilitates adapting an equipment

from one system to another system.

The process is a sequence consisting of selection of an emitter port and a receptor port and then examining the type, connection, location, wire routing, etc., to determine if a coupling path exists. If a path does exist, the received signal is computed at the receptor and compared to the susceptibility level. In addition to the emitter-receptor port pair analysis, the program also computes the total signal from all emitters coupled into each receptor acting simultaneously.

A sampled spectrum technique in which each spectrum amplitude is sampled at various frequencies across the range of interest is used. MIL-STD-461A requires three sample frequencies per octave from 30 Hz to 18 GHz, providing approximately 90 sample frequencies. This degree of resolution appears reasonable for EMC specifications since the limits of emission and susceptibilities are fairly constant over large regions of the spectrum. Additionally, none of the individual requirements cover the total frequency range, so much less than 90 data points per spectrum may be used. If greater resolution is desired, IEMCAP allows the user to specify levels at individual frequencies. In addition, IEMCAP samples the spectrum in the interval half-way between the sample frequency and each of its neighboring sample frequencies in order to avoid missing narrow peaks or nulls between sample frequencies. The maximum level in the interval is used for emission spectra and the minimum level is used for susceptibility spectra. This quantizes the spectra with respect to the sample frequencies in a fail safe direction. A table of sample frequencies is defined for an equipment, and all spectra of ports within that equipment are quantized at these frequencies.

The user has two options with respect to the equipment frequency tables. He may specify the upper and lower frequency limits, the maximum number of frequencies to use, and the number of frequencies per octave. The program will then generate a table of geometrically spaced frequencies within the specified limits. Optionally, he may specify the upper and lower frequency limits, the maximum number of frequencies, and a number of specific frequencies of interest. The program will then generate geometrically spaced frequencies to fill in the number of frequencies not specified. The program will accept any range from 30 Hz to 18 GHz, but if desired, the user may concentrate all 90 frequencies over a smaller interval within this range.

Each port is categorized into one of six types (based on function). Each type has its own range of frequencies within the overall frequency range. These ranges, adapted from MIL-STD-461/462 ranges for the port function, are shown in Table C-3. The non-required spectrum model assumes zero emission and susceptibility outside these ranges. The quantized spectra and amplitudes within up to 90 contiguous intervals across the frequency range of interest is thus generated by the program.

TABLE C-3
PORT EMISSION AND SUSCEPTIBILITY TESTS AND FREQUENCY RANGES

PORT FUNCTION	EMITTER		RECEPTOR	
	MIL-STD-462 Test (s)	Freq Range (Hz)	MIL-STD-462 Test (s)	Freq Range (Hz)
RF	CE06	14K-18G	CS04	14K-18G
Power	CE02/03	30-50M	CS01/02	30-400M
Signal	CE02/04	30-1G	CS02/04	30-10G
Control	CE02/04	30-1G	CS02/04	30-10G
EED	-------	-------	CS02/04	30-10G
Eqpt Case	RE02	14K-10G	RS03/04	14K-10G

This representation allows the program to be divided into two sections, each running in approximately 70K (decimal) of core memory. One section of the program contains the input data management and spectrum model routines (IDIPR), and the other contains the analysis and transfer model routines (TART). Each section is executed separately so that both are not in core at one time. This provides a flexible program, readily adaptable to a wide variety of computer. Machine-dependent techniques, such as overlaying, are not used.

The maximum system size per computer run is shown in Table C-4. For each equipment, the 15 ports include the case leakage. Therefore, 14 intentional ports are allowed.

TABLE C-4

MAXIMUM SYSTEM SIZE

EQUIPMENTS	40
PORTS PER EQUIPMENT	15
TOTAL PORTS (40 x 15)	600
APERTURES	10
ANTENNAS	50
FILTERS	20
WIRE BUNDLES	10
SEGMENTS PER BUNDLE	10
WIRES PER BUNDLE	50

2.4 IEMCAP Operation

The Input Decode and Initial Processing Routine (IDIPR) is the first part of IEMCAP. It is divided into three basic routines. The Input Decode Routine (IPDCOD) read and decodes the free-field input data from punched cards and checks the data for errors. Next is the Initial Processing Routine (IPR). This routine performs data management, interfaces with spectrum models, and generates the working files. The data base defining the system/subsystem/equipment characteristics is stored on a magnetic disc or tape called the Intrasystem File (ISF). The program then enters the Wire Map Routine which generates cross-reference map arrays for use by the wire coupling math models during analysis. At this point, execution of IDIPR terminates.

The second section of IEMCAP, called the Task Analysis Routine (TART) uses the data provided by IDIPR to perform one of the four analysis task listed below.

a. Specification Generation - This subroutine adjust, within specified limits, the initial non-required emission and susceptibility spectra, attempting to make the system compatible. A summary of interference situations is printed.

b. Baseline System EMC Survey - The subroutine analyzes the system for interference. If the maximum of the EMI point margins over the frequency range for a coupled emitter-receptor pair exceeds the user specified printout limit, a summary of the interference is printed. Total received signal into each receptor from all emitters is also printed.

c. Trade-Off Analysis - This subroutine compares the interference from two EMC analysis runs. The effect on interference of antenna changes, filter changes, spectrum parameter changes, wire changes etc., can be assessed from this analyses.

d. Specification Waiver Analysis - This subroutine allows adjustments to selected port spectrums (often to represent a waiver request) and evaluates the impact of this change."

2.5 Emitter Models

The emitter models relate the parameters of the equipment and port data to the power spectral density output at the emitter port. Many emitter models are incorporated in the program in the SCARFE routine for common emitter types, and provision is made for user input of spectral densities for those types not modeled. A few of the emitter models are listed below:

a. Analog modulation representations, such as AM. AM-DSB/SC, SSB, and FM, either voice, clipped voice, or non-voice.

b. Digital modulation representations, such as PDM, PCM/AM, PPM/AM, PAM/FM, or binary FSK.

c. Pulse modulation representations (rectangular, trapezoidal, triangular, Gaussian, Chirp, damped sinusoid, sawtooth, exponential, etc.).

d. CW

The user has the option of augmenting the emitter models with selected filter functions.

2.6 Receptor Models

The basic approach for RF receptors used in IEMCAP is to accept input data on in-band sensitivity, along with a bandwidth parameter, and then to form a susceptibility function in the required spectra defined by user-adjusted military specification interference limits as designated. An RF receiver representation in the program will, in general, have a trapezoidal shaped susceptibility function (in-band) due to the skirt slopes of the normal selectivity curve. The susceptibility of an RF port is assumed to be equal to the tuned sensitivity of the receiver, as provided in the input data, over the entire frequency range defined by the user-specified bandwidth. The susceptibility of a signal or control port is to be equal to the

operating level, less 20 dB. This somewhat arbitrary susceptibility level is based on characteristics of common avionics equipments. The user may define a higher or lower susceptibility level in the required range of a signal or control port by specifying a higher or lower operating level.

In the case of receivers where more is known about the details of the response curve than just the flat response discussed above, the user can specify the known response curve by a discrete spectrum of up to ten frequencies with associated levels. The user has an additional option of augmenting the receptor models with selected filter functions. The filter models modify the levels of a given emitter signal at the receptor by the level at the filter output terminals for compatibility analysis.

2.7 Transfer Models

The transfer models are designed to compute the ratio (path gain) between the energy output at an emitter port and that present at the input to a receptor port. For example, the antenna-to-antenna transfer model computes the ratio of the energy output of a transmitter to the energy at the input of the receptor. Receptor models then relate the energy spectrum at the receptor port to the response produced by that spectrum. This latter calculation is based on the susceptibility-versus-frequency response of the receptor.

2.8 Filter Models

Seven filter models are used in IEMCAP: single tuned, transformer coupled, Butterworth tuned, low pass, high pass, and band reject. The models represent filters as ideal, lossless networks, made up only of reactive elements (capacitors and inductors). The filter transfer models calculate the

insertion loss in dB provided by a filter at a given frequency, i.e., the reduction in delivered power due to insertion of a filter along with a limit or "floor" to more accurately represent actual filters. Provision is made for the entry of a minimum insertion loss to represent the effect of the filter at the tuned frequency or in the pass band.

2.9 Antenna Model

Antennas are categorized into two groups. The first group includes low gain antenna types such as a monopole, dipole, slot or loop antennas. Antennas included in the second group are medium to high gain types, such as those using horns or parabolic reflectors. All antennas in the first group are modeled analytically by trigonometric expressions. A dipole, for example, has a directive gain $G_d = 1.6 \sin^2 \theta$, where θ is the angle of an arbitrary direction with respect to the dipole axis. All antennas in the second group are modeled by a three dimensional three-sector representation. Each sector subtends a solid angle in the unit sphere and has an associated antenna gain level.

2.10 Antenna-to-Antenna Coupling

Far-field coupling between antennas located above a ground plane is analyzed using an ECAC-developed Simplified Theoretical Ground-Wave Model. A smooth, curved earth is assumed, with the model treating both direct and reflected effects. The model includes the line-of-sight, diffraction, and tropospheric regions. Coupling between antennas aboard an aircraft or spacecraft is analyzed using an Intravehicular-Propagation Model that takes into account vehicle geometry to compute shading and diffraction losses. The model has been extensively documented by the Air Force.

2.11 Field-to-Wire Coupling

Coupling from environmental electromagnetic fields onto wiring usually occurs via the fields entering through dielectric aperatures in the system's skin and coupling to immediately adjacent wires. Exposed wires are assumed to be adjacent to the aperture, and the amount of RF energy coupled is determined as a function of aperture size and location. A transmission line model is then used to compute the currents induced in the wires. Worst-case electromagnetic field vector orientation is determined and used for the calculation.

2.12 Wire-to-Wire Coupling

If any wires connected to any of the emitter ports are in the same bundle as wires connected to the receptor port, the wire-to-wire coupling routine is called. This routine computes the spectral voltages induced in the receptor circuit by the emitter circuit. These calculations are performed on a pair basis (only one emitter circuit considered to couple with the receptor circuit for each calculation), with the effects of all other circuits neglected during this calculation. Each possible pair coupling is computed, and the total coupling is calculated by summing all of the maximum pair couplings over the interval without regard to phase. The validity of this wire-to-wire coupling model has been verified by experimental data.

2.13 Case-to-Case Coupling

This routine calculates coupling between cases in the system. The case is considered a point at its center. The model assumes dipole antennas and $1/r^3$ field falloff.

2.14 System Model

The system model is used to relate the manner in which the emitter, transfer and receptor models are combined. It is designed to account for simultaneous operation of all equipments. This enables calculations for compatibility and specification generation to be performed not only between pairs of equipments, but also among all equipments, when more than one equipment operates simultaneously.

2.15 System/Subsystem Specification Generation

The Specification Generation Routine (SGR) attempts to adjust the non-required portions of the port spectra, initially computed in IPR, to produce a compatible system. These spectra are considered limits. Thus an emitter cannot generate outputs greater than the non-required spectrum levels, and a receptor cannot respond to received signals less than these levels, or interference will result. For the analysis, each port is initially assumed to emit and respond at these levels. For each emitter-receptor port pair in the system with a coupling path between them, the received signal is computed using the assumed maximum emission levels. This signal is compared to the assumed minimum susceptibility levels over the frequency range. Where the susceptibility level is exceeded in the emitter non-required range, the emission levels are reduced such that the margin is equal to the user-defined adjustment safety margin, or to the adjustment limit level, whichever is greater.

After each emitter has been adjusted in conjunction with each receptor, the receptor spectra are adjusted. The received signal from each emitter with a coupling path to a given receptor is computed using the adjusted emission spectra and summed. The susceptibility spectrum levels are then compared to

this total signal, and where the level is exceeded in the non-required range, the susceptibility is raised such that the margin is equal to the user-defined adjustment safety margin, or to the adjustment limit level, whichever is less.

This process provides a set of port spectra specifications such that the system will be compatible if they are not exceeded. These become EMC specification limits to which the equipment ports can be tested.

After the adjustment process, a number of port pairs may exist which are still incompatible. This unresolved interference results from required emissions and responses, non-required spectra adjusted to their limits, and from non-adjustable spectra of previously procured equipments. Consequently, after receptor adjustment, SFR recomputes the interference between adjusted emitters and adjusted receptors. If the maximum of the EMI point margin exceeds a user specified limit, the case is printed out as unresolved interference, along with a summary of the spectrum levels and the EMI margins.

2.16 Outputs

A variety of outputs are provided by IEMCAP, the major outputs include:

A. Intrasystem Signature File Report - a data base summary that includes a printout of system and equipment characteristics, as well as equipment frequency tables and spectra.

B. Specification Generation Outputs - Outputs are provided for the three phases of the Spec Generation Routine: an Adjusted Emitter Spectra Summary, a Receptor Spectrum Summary Adjustment and an unresolved Interference Summary. After these, the finally adjusted spectra are summarized for each port. An example partial summary of the adjusted emitter broadband and narrowband spectra is

shown in Figure C-2. After a given receptor port has been adjusted, Spectrum Generation Routine scans through the emitters coupled to it and computes the margins. If the maximum margin exceeds the user specified printout limit, a partial summary is printed, as illustrated in Figure C-3. Printouts can also be provided for baseline system EMI survey outputs, trade-off, and waiver outputs.

C. Baseline System EMC Survey Outputs - This output summarizes the conditions of coupling for the relevant frequencies of cases where the maximum EMI margin exceeds the margin print limit.

D. Trade-off and Waiver Outputs - These outputs are similar to the baseline survey outputs, except margin changes are listed when applicable.

E. Supplemental Outputs - Details of the Antenna/Antenna, Antenna/Wire, and Wire/Wire coupling routines can be provided by calling for special outputs. For example, the supplement output for Antenna/Antenna coupling provides location coordinates, main beam angles, look angles, and antenna gains. Path loss parameters, and the frequency-dependent loss characteristics are then presented. The same level of details are furnished for the other routines.

A D J U S T E D   E M I T T E R   S P E C T R A

EMTR -- SUBS = AVION EQPT 1 = CURT1 PORT 4 = MIKI1

RCPT -- SUBS = UCON1 EQPT 3 = UCON1 PORT 2 = AUDI1

PATH = WIRE TO WIRE

FREQUENCY (HERTZ)	FREQ BASE	TRANSFER RATIO	NARROWBAND ADJSTD EMI MGN	RCVD SIGNAL	ADJ EMTR SPCT LEV	ADJMT AMOUNT	SPCT LEV TO LIMIT	ADJSTD EMI MGN	R SI
0.30000E 02	EMTR	REQD-104.8						-166.8	-10
0.45000E 02	EMTR	REQD-101.4						-158.2	-9
0.70000E 02	EMTR	REQD -97.7						-149.8	-8
0.10000E 03	EMTR	REQD -94.7						-144.8	-7
0.20000E 03	EMTR	REQD -88.7						-140.0	-7
0.10000E 04	EMTR	REQD -74.8						-130.3	-6
0.40000E 04	EMTR	REQD -62.8						-122.7	-5
0.44000E 04	EMTR	REQD -61.9						-124.5	-5
0.45000E 04	EMTR	-61.7	-52.1	50.9	112.6	0.	100.0	-90.1	1
0.31850E 09	EMTR	2.9	-80.2	22.9	20.0	0.	100.0	-32.1	7
0.31850E 09	EMTR	2.9	-80.2	22.9	20.0	0.	100.0	-32.1	7
0.32050E 09	EMTR	2.9	-80.2	22.9	20.0	0.	100.0	-32.1	7
0.32100E 09	EMTR	2.9	-80.2	22.9	20.0	0.	100.0	-32.1	7
0.32100E 09	EMTR	2.9	-80.2	22.9	20.0	0.	100.0	-32.1	7
0.32100E 09	EMTR	2.9	-80.2	22.9	20.0	0.	100.0	-32.1	7
0.32100E 09	EMTR	2.9	-80.2	22.9	20.0	0.	100.0	-32.1	7
0.32100E 09	EMTR	2.9	-80.2	22.9	20.0	0.	100.0	-32.1	7
0.32100E 09	EMTR	2.9	-80.2	22.9	20.0	0.	100.0	-32.1	7
0.32100E 09	EMTR	2.9	-80.2	22.9	20.0	0.	100.0	-32.1	7
0.32100E 09	EMTR	2.9	-80.2	22.9	20.0	0.	100.0	-32.1	7
0.32100E 09	EMTR	2.9	-80.2	22.9	20.0	0.	100.0	-32.1	7
0.32100E 09	EMTR	2.9	-80.2	22.9	20.0	0.	100.0	-32.1	7
0.32100E 09	EMTR	2.9	-80.2	22.9	20.0	0.	100.0	-32.1	7
0.32100E 09	EMTR	2.9	-80.2	22.9	20.0	0.	100.0	-32.1	7
0.32100E 09	EMTR	2.9	-80.2	22.9	20.0	0.	100.0	-32.1	7
0.32150E 09	EMTR	2.9	-80.2	22.9	20.0	0.	100.0	-32.1	7
0.32350E 09	EMTR	2.9	-80.2	22.9	20.0	0.	100.0	-32.0	7
0.32350E 09	EMTR	2.9	-80.2	22.9	20.0	0.	100.0	-32.0	7
0.48150E 09	EMTR	3.1	-79.9	23.1	20.0	0.	100.0	-28.3	7
0.64199E 09	EMTR	3.4	-79.6	23.4	20.0	0.	100.0	-25.5	7
0.64199E 09	EMTR	3.4	-79.6	23.4	20.0	0.	100.0	-25.5	7
0.64200E 09	EMTR	3.4	-79.6	23.4	20.0	0.	100.0	-25.5	7
0.64201E 09	EMTR	3.4	-79.6	23.4	20.0	0.	100.0	-25.5	7
0.64201E 09	EMTR	3.4	-79.6	23.4	20.0	0.	100.0	-25.5	7
0.80250E 09	EMTR	3.7	-79.4	23.7	20.0	0.	100.0	-23.3	7
0.96299E 09	EMTR	3.9	-79.1	23.9	20.0	0.	100.0	-21.5	8
0.96299E 09	EMTR	3.9	-79.1	23.9	20.0	0.	100.0	-21.5	8
0.96300E 09	EMTR	3.9	-79.1	23.9	20.0	0.	100.0	-21.5	8
0.96301E 09	EMTR	3.9	-79.1	23.9	20.0	0.	100.0	-21.5	8
0.96301E 09	EMTR	3.9	-79.1	23.9	20.0	0.	100.0	-21.5	8

INTEGRATED EMI MARGIN = 18.2

FIGURE C-2

PARTIAL SUMMARY OF ADJUSTED EMITTER SPECTRA

PECTRA

RT 4 = MIKI1

RT 2 = AUDI1

PCT LEV O LIMIT	BROADBAND ADJSTD EMI MGN	RCVD SIGNAL	ADJ EMTR SPCT LEV	ADJMT AMOUNT	SPCT LEV TO LIMIT	BDWTH FCTR
	-166.8	-100.8	85.9	0.	100.0	-31.5
	-158.2	-92.2	89.4	0.	100.0	-31.5
	-149.8	-83.7	92.2	0.	100.0	-31.5
	-144.8	-78.7	92.6	0.	100.0	-31.5
	-140.0	-74.0	88.4	0.	100.0	-31.5
	-130.3	-64.3	77.2	0.	100.0	-31.5
	-122.7	-56.6	66.8	0.	100.0	-31.5
	-124.5	-58.5	63.7	0.	100.0	-31.5
100.0	-90.1	12.9	132.0	0.	100.0	-28.7
100.0	-32.1	70.9	50.0	0.	100.0	9.0
100.0	-32.1	70.9	50.0	0.	100.0	9.0
100.0	-32.1	70.9	50.0	0.	100.0	9.0
100.0	-32.1	70.9	50.0	0.	100.0	9.0
100.0	-32.1	70.9	50.0	0.	100.0	9.0
100.0	-32.1	70.9	50.0	0.	100.0	9.0
100.0	-32.1	70.9	50.0	0.	100.0	9.0
100.0	-32.1	70.9	50.0	0.	100.0	9.0
100.0	-32.1	70.9	50.0	0.	100.0	9.0
100.0	-32.1	70.9	50.0	0.	100.0	9.0
100.0	-32.1	70.9	50.0	0.	100.0	9.0
100.0	-32.1	70.9	50.0	0.	100.0	9.0
100.0	-32.1	70.9	50.0	0.	100.0	9.0
100.0	-32.1	70.9	50.0	0.	100.0	9.0
100.0	-32.1	70.9	50.0	0.	100.0	9.0
100.0	-32.1	70.9	50.0	0.	100.0	9.0
100.0	-32.1	71.0	50.0	0.	100.0	9.1
100.0	-32.0	71.0	50.0	0.	100.0	9.1
100.0	-32.0	71.0	50.0	0.	100.0	9.1
100.0	-28.3	74.7	50.0	0.	100.0	10.8
100.0	-25.5	77.5	50.0	0.	100.0	12.1
100.0	-25.5	77.5	50.0	0.	100.0	12.1
100.0	-25.5	77.5	50.0	0.	100.0	12.1
100.0	-25.5	77.5	50.0	0.	100.0	12.1
100.0	-25.5	77.5	50.0	0.	100.0	12.1
100.0	-23.3	79.7	50.0	0.	100.0	13.0
100.0	-21.5	81.5	50.0	0.	100.0	13.8
100.0	-21.5	81.5	50.0	0.	100.0	13.8
100.0	-21.5	81.5	50.0	0.	100.0	13.8
100.0	-21.5	81.5	50.0	0.	100.0	13.8
100.0	-21.5	81.5	50.0	0.	100.0	13.8

RE C-2

STED EMITTER SPECTRA

UNRESOLVED INTEPFEF

EMTR -- SUBS = AVION EQPT 1 = CURT1 PORT

RCPT -- SUBS = UCON1 EQPT 3 = UCON1 PORT

PATH = WIRE TO WIRE

NOTE - R = IN REQD RANGE, I = INTERPOLATEL

						+----------NARROWBAN		
FREQUENCY (HERTZ)	FREQ BASE	TRANSFER RATIO	RECEPTOR SPCT LEV		RCPT LEV TO LIMIT	EMI MARGIN	EMITTER SPEC LEV	EMTE TO I
0.30000E 02	EMTR	-104.8	66.0	IR				
0.45000E 02	EMTR	-101.4	66.0	R				
0.70000E 02	EMTR	-97.7	66.0	R				
0.10000E 03	EMTR	-94.7	66.0	R				
0.20000E 03	EMTR	-88.7	66.0	R				
0.10000E 04	EMTR	-74.8	66.0	R				
0.40000E 04	EMTR	-62.8	66.0	R				
0.44000E 04	EMTR	-61.9	66.0	R				
0.45000E 04	EMTR	-61.7	103.0	I		-52.1	112.6	10
0.31850E 09	EMTR	2.9	103.0	I		-80.2	20.0	10
0.31850E 09	EMTR	2.9	103.0	I		-80.2	20.0	10
0.32050E 09	EMTR	2.9	103.0	I		-80.2	20.0	10
0.32100E 09	EMTR	2.9	103.0	I		-80.2	20.0	10
0.32100E 09	EMTR	2.9	103.0	I		-80.2	20.0	10
0.32100E 09	EMTR	2.9	103.0	I		-80.2	20.0	10
0.32100E 09	EMTR	2.9	103.0	I		-80.2	20.0	10
0.32100E 09	EMTR	2.9	103.0	I		-80.2	20.0	10
0.32100E 09	EMTR	2.9	103.0	I		-80.2	20.0	10
0.32100E 09	EMTR	2.9	103.0	I		-80.2	20.0	10
0.32100E 09	EMTR	2.9	103.0	I		-80.2	20.0	10
0.32100E 09	EMTR	2.9	103.0	I		-80.2	20.0	10
0.32100E 09	EMTR	2.9	103.0	I		-80.2	20.0	10
0.32100E 09	EMTR	2.9	103.0	I		-80.2	20.0	10
0.32100E 09	EMTR	2.9	103.0	I		-80.2	20.0	10
0.32100E 09	EMTR	2.9	103.0	I		-80.2	20.0	10
0.32150E 09	EMTR	2.9	103.0	I		-80.2	20.0	10
0.32350E 09	EMTR	2.9	103.0	I		-80.2	20.0	10
0.32350E 09	EMTR	2.9	103.0	I		-80.2	20.0	10
0.48150E 09	EMTR	3.1	103.0	I		-79.9	20.0	10
0.64199E 09	EMTR	3.4	103.0	I		-79.6	20.0	10
0.64199E 09	EMTR	3.4	103.0	I		-79.6	20.0	10
0.64200E 09	EMTR	3.4	103.0	I		-79.6	20.0	10
0.64201E 09	EMTR	3.4	103.0	I		-79.6	20.0	10
0.64201E 09	EMTR	3.4	103.0	I		-79.6	20.0	10
0.80250E 09	EMTR	3.7	103.0	I		-79.4	20.0	10
0.96299E 09	EMTR	3.9	103.0	I		-79.1	20.0	10
0.96299E 09	EMTR	3.9	103.0	I		-79.1	20.0	10
0.96300E 09	EMTR	3.9	103.0	I		-79.1	20.0	10
0.96301E 09	EMTR	3.9	103.0	I		-79.1	20.0	10
0.96301E 09	EMTR	3.9	103.0	I		-79.1	20.0	10

INTEGRATED EMI MARGIN = 15.2

RCPT= UCON1-MIKO1 FROM EMTR=CURT1-AUDO1 IPATH = 3

FIGURE C-3

PARTIAL SUMMARY OF SGR

R E S O L V E D   I N T E R F E R E N C E

UBS = AVION EQPT 1 = CURT1 PORT 4 = MIKI1

UBS = UCON1 EQPT 3 = UCON1 PORT 2 = AUDI1

IRE TO WIRE

= IN REQD RANGE, I = INTERPOLATED VALUE

RCPT LEV TO LIMIT	NARROWBAND EMI MARGIN	EMITTER SPEC LEV	EMTR LEV TO LIMIT	RCVD SIGNAL	BROADBAND EMI MARGIN	EMITTER SPEC LEV		EMTR LEV TO LIMIT	RCVD SIGNAL	BDWTH FCTR
R					-166.8	85.9	R	100.0	-100.8	-31.5
R					-158.2	89.4	R	100.0	-92.2	-31.5
R					-149.8	92.2	R	100.0	-83.7	-31.5
R					-144.8	92.6	R	100.0	-78.7	-31.5
R					-140.0	88.4	R	100.0	-74.0	-31.5
R					-130.3	77.2	R	100.0	-64.3	-31.5
R					-122.7	66.8	R	100.0	-56.6	-31.5
R					-124.5	63.7	R	100.0	-58.5	-31.5
	-52.1	112.6	100.0	50.9	-90.1	132.0		100.0	12.9	-28.7
	-80.2	20.0	100.0	22.9	-32.1	50.0		100.0	70.9	9.0
	-80.2	20.0	100.0	22.9	-32.1	50.0		100.0	70.9	9.0
	-80.2	20.0	100.0	22.9	-32.1	50.0		100.0	70.9	9.0
	-80.2	20.0	100.0	22.9	-32.1	50.0		100.0	70.9	9.0
	-80.2	20.0	100.0	22.9	-32.1	50.0		100.0	70.9	9.0
	-80.2	20.0	100.0	22.9	-32.1	50.0		100.0	70.9	9.0
	-80.2	20.0	100.0	22.9	-32.1	50.0		100.0	70.9	9.0
	-80.2	20.0	100.0	22.9	-32.1	50.0		100.0	70.9	9.0
	-80.2	20.0	100.0	22.9	-32.1	50.0		100.0	70.9	9.0
	-80.2	20.0	100.0	22.9	-32.1	50.0		100.0	70.9	9.0
	-80.2	20.0	100.0	22.9	-32.1	50.0		100.0	70.9	9.0
	-80.2	20.0	100.0	22.9	-32.1	50.0		100.0	70.9	9.0
	-80.2	20.0	100.0	22.9	-32.1	50.0		100.0	70.9	9.0
	-80.2	20.0	100.0	22.9	-32.1	50.0		100.0	70.9	9.0
	-80.2	20.0	100.0	22.9	-32.1	50.0		100.0	70.9	9.0
	-80.2	20.0	100.0	22.9	-32.1	50.0		100.0	70.9	9.0
	-80.2	20.0	100.0	22.9	-32.1	50.0		100.0	71.0	9.1
	-80.2	20.0	100.0	22.9	-32.0	50.0		100.0	71.0	9.1
	-80.2	20.0	100.0	22.9	-32.0	50.0		100.0	71.0	9.1
	-79.9	20.0	100.0	23.1	-28.3	50.0		100.0	74.7	10.8
	-79.6	20.0	100.0	23.4	-25.5	50.0		100.0	77.5	12.1
	-79.6	20.0	100.0	23.4	-25.5	50.0		100.0	77.5	12.1
	-79.6	20.0	100.0	23.4	-25.5	50.0		100.0	77.5	12.1
	-79.6	20.0	100.0	23.4	-25.5	50.0		100.0	77.5	12.1
	-79.6	20.0	100.0	23.4	-25.5	50.0		100.0	77.5	12.1
	-79.4	20.0	100.0	23.7	-23.3	50.0		100.0	79.7	13.0
	-79.1	20.0	100.0	23.9	-21.5	50.0		100.0	81.5	13.8
	-79.1	20.0	100.0	23.9	-21.5	50.0		100.0	81.5	13.8
	-79.1	20.0	100.0	23.9	-21.5	50.0		100.0	81.5	13.8
	-79.1	20.0	100.0	23.9	-21.5	50.0		100.0	81.5	13.8
	-79.1	20.0	100.0	23.9	-21.5	50.0		100.0	81.5	13.8

GIN = 15.2
1 IPATH = 3

FIGURE C-3

PARTIAL SUMMARY OF SGR OUTPUT

3.0 GEMACS

GEMACS is the General Electromagnetic Model for the Analysis of Complex Systems. The objective of this model is to provide the designer with EM field data in the near and far-field. Electrical currents, antenna input impedance and antenna coupling for a complex physical configuration are modeled. The Method of Moments(MOM) technique is used to develop these data for wire antennas on structures represented by wire grid models.

Electromagnetic/near-field interactions are those occurring between systems along paths that are similar or shorter in length than $2d^2/\lambda$ where λ is the wavelength and d is the significant characteristic dimension of the antenna (e.g., the diameter of a dish antenna). One example is the interaction between different antennas which are closely grouped. Another example is the interaction between an antenna of one system and a nearby cable belonging to another system.

All electromagnetic phenomena are described by Maxwell's integral equations. In any particular case, the defining integral equation is replaced with a matrix equation and is solved by matrix inversion or by iterative techniques. The boundary conditions are imposed directly, and the matrix solution procedure yields the current distribution that fits the boundary conditions imposed. The structure of the antenna may be very complex, but the method does not change. Complex structures are treated almost as easily as simple ones, since prior knowledge of the current distribution is not required. However, once the current distribution has been calculated, other quantities of interest may be calculated.

A general computer program has been written in FORTRAN IV that cal-

culates the current distribution on the individual wires in an arbitrary geometry. The only required inputs are the known electrical and physical parameters of the system. The currents are then used to calculate the three components of the electric field intensities in the near and far-fields of the array. The mutual coupling and impedance between elements of the array can be calculated, as well as the input impedance of each antenna. A multi-diagonal or banded matrix technique is used in an iterative algorithm. The basis for the calculations is the method of moments.

4.0 PSTAT

The Precipitation Static Electricity Program was designed to predict short circuit antenna currents and equivalent noise fields produced by corona and streamer discharges in an airborne avionics system. The computer code is divided into two models. One model for corona discharge and one model for streamer noise.

Static electricity or triboelectric charging occurs when an aircraft or missile encounters precipitation and cloudy conditions and/or when the potential of the vehicle or parts of the vehicle reach a level where electrical breakdown of the air occurs. Electricity usually discharges from points of high dc fields on the aerospace vehicle. The electrical breakdowns take the form of corona discharges from these extremities or as streamer discharges across plastic-composite material surfaces. These noise surfaces can adversely effect such C&E equipment as digital avionics, airborne radio communications, navigation receivers, glide-scope receivers, automated digital control equipment, and electromagnetic devices.

The use of nonmetal surfaces adjacent to exposed metal surfaces, including flush-mounted antenna structures, in high-performance aircraft and aerospace vehicles operating in or through the atmosphere has increased the hazards to static electricity. Studies of frictional electrification resulting from the impact of particles at supersonic speeds show that the intensity of the generated interference is proportional to the magnitude of the current discharged. The interference level is dependent upon coupling between the affected circuits and the location of the discharge noise source. The locations of the discharge noise sources are determined by the geometry of the aircraft and the aircraft potential. The potential is a function of charging current. A knowledge of the vehicle charging processes and the magnitudes of the resulting charging currents is essential in order to determine the magnitude of the interference that will be encountered.

The objective of the computer code is to provide a capability for modeling and analysis of static electricity sources and transfer as an engineering design tool. The present code is able to analyze and predict the noise fields at the middle, top fuselage and fin cap areas of conventional aircraft shapes. Further development to include other features is contemplated.

5.0 LIGHTNING

The lightning program is modeled as two computer codes, APERTURE and DIFFUSION. These codes calculate the magnitude of lightning induced voltages in aircraft due to coupling through an aperture, and diffusion around the surface. Lightning can have two basic origins: storms or some human modification of the natural atmospheric environment.

Storm-produced lightning flashes may reach energy levels of approximately 280,000 amperes over a 100 usec period, followed by lesser surges of 1000 amperes for 1 to 200 msec. An average lightning flash generates levels greater than 40,000 amperes. Triggered lightning generally results from the introduction of a long electrical conductor into a thunderstorm environment in which the electrical field is approximately 10 kilovolts per meter. When the potential difference between the tip of the conductor and the ambient atmosphere becomes about one million volts, triggered lightning can occur.

Electrical power controls, wiring systems, C&E equipment, and electromagnetic instruments installed in aerospace vehicles and ground facilities are susceptible to transient voltages induced by lightning strikes. The electrical energy radiated and the magnetic fields generated by nearby lightning flashes that are not direct strikes produce significant hazards to modern electronic systems. Such systems function at low signal levels and use digital circuitry and solid-state components with wideband and fast time-response characteristics. In addition, metals are being widely replaced by new composite materials with significantly less effective shielding properties. These composites are more vulnerable to the direct and radiated lightning threats.

Present practices in lightning protection of aircraft deal predominantly with what may be called the "direct effects" of lightning; including burning, blasting, and physical deformation of skins and structural elements. The radiation fields due to lightning vary with time and frequency and with distance from the discharge. Generally, the variations in time and frequency are correlated with the different stages of the lightning flash. The radiation

from lightning consists of many pulses: a single lightning flash can generate approximately 10^4 identifiable pulses for frequencies from quasi-dc to 100 GHz. The radiated fields corresponding to 3 volts/meter at distances of 100 km, can be of sufficient amplitude to cause interference and affect the performance of C&E equipment.

6.0 NCAP

The Nonlinear Circuit Analysis Program models nonlinear transfer functions in an electronic circuit. Nonlinear networks are solved by premultiplying a generator vector by the inverse of the first-order nodal vector matrix. The results of this procedure are the elements, which are the first-order transfer functions at all modes in the network at a given excitation frequency. For higher order transfer functions an interactive procedure is utilized.

There are two major kinds of nonlinear interactions responsible for a large and especially difficult class of interference problems: one occurs inside equipment; the other is due to the phenomenon known as the "rusty bolt" effect. Intra-equipment nonlinear interaction can be caused by the cross-modulation products resulting from coexistence of a desired and an interfering signal in the detector stage of a receiver or in some transmitter output stages. This type of interference can be handled by equipment models that account for the nonlinear behavior of circuits.

The Signatron Company, under contract to RADC, has done substantial work in the modeling of communication receiver interference. A major objective of this program was to develop mathematical models of communication receivers that permit close prediction of the degradation caused by the gen-

eral classes of interfering signals. Basically, the emphasis was placed upon accurate characterization of nonlinear circuits and systems. Hence, the effort has broad application in areas beyond that of communication receivers.

In order to determine how a general interference (e.g., narrowband, wideband, multiple signal) degrades a received signal, it is sufficient to have a "black-box" model of the communication receiver. A realistic model must be nonlinear to account for such effects as desensitization, cross-modulation, inter-modulation distortion, and spurious responses. Black-box, nonlinear canonic models of portions of communication receivers, have been developed leading to a representation of the receiver in terms of receiver-independent building blocks of known form multipliers, and receiver-dependent parameters. Since the number of parameters required will generally be much smaller than the number of devices and components in the receiver, this approach provides a practical means of analyzing and simulating the input/output behavior of the receiver as a non-linear signal-processing black-box.

The parameters for canonic nonlinear models of a communication receiver are determined by the nonlinear transfer functions of the receiver. These functions can be derived by circuit-analysis techniques. Experimental results have been obtained that validate the nonlinear modeling and analysis of communication receiver nonlinear responses to multi-signal inputs. Nonlinear transfer functions and nonlinear canonic models have been derived and compared with measured results for a single-stage transistor amplifier, a two-stage tuned transistor amplifier, a VHF solid-state communications receiver, and an HF vacuum-tube communication receiver. These results have demonstrated that the use of the nonlinear-transfer-function approach, based

on the Volterra series, make it possible to predict accurately the frequency dependence as well as the input amplitude dependence of receiver responses for multiple input signals.

The second major type of nonlinear interaction is sometimes referred to as the "rusty bolt" effect. The prototypical case is one of a bolt holding together two pieces of steel, e.g., the plates in a ship's hull or the structural members of a tower, between which some rust has developed. The oxidized metal, in contact with unoxidized metal parts, acts like a semiconductor junction. When two or more signals flow through this junction, cross-modulation products can be formed that can cause interference in a susceptible receiver or receptor. If the character and location of such accidental zones of nonlinear activity were known, the calculation of interference could be straightforwardly carried out.

7.0 ADDITIONAL CODES

The IAP codes noted above operate in a "stand alone" mode. The lightning model and the PSTAT code interface with IEMCAP through one of IEMCAP's input data parameters. The other models are used to study specific potential interference problems. Additional codes including an advanced lightning model, magnetospheric substorm effects model, and TEMPEST are in development. Aircraft stores and Electro-explosive devices and systems and advanced composite materials are also of interest in the IAP.

7.1 Magnetospheric Substorms

During magnetospheric substorms, the dark insulated surfaces of spacecraft may charge to negative potentials in excess of many kilovolts. Anomalies in the performance of spacecraft systems have been attributed to EM

interference from discharges, surface damage from discharges, and contamination by electrostatic deposition. The following paragraphs briefly describe the phenomena.

Magnetospheric substorms appear to be governed by magnetic-field reconnection in the earth's magnetotail. During substorms, large clouds of energetic electrons are injected into closed field-line regions. At synchronous altitude, the injection usually occurs between midnight and dawn, local time. The fluxes of energetic electrons can exceed fluxes of lower-energy plasmasphere electrons. (Plasmasphere is the region of dipolar, relatively closed, field lines and stably trapped particles. There is a sharp step on the outer boundary of the plasmasphere called the "plasma-pause.") When this occurs, parts of the spacecraft surface which are in darkness may charge. A spacecraft may charge also in sunlight if the flux of substorm electrons exceeds the photoelectron flux from the surface of the spacecraft.

Primarily because unequal numbers of electrons and ions collide with and are absorbed by an initially neutral spacecraft, and secondarily because a sunlit spacecraft emits photoelectrons, a space vehicle will acquire a net charge. Depending upon the characteristic properties of the plasma medium and of the spacecraft's surfaces, the potentials of the surfaces can range from about -10 kilovolts to +2 volts. Serious (kilovolt) charging occurs only in the magnetospheric beyond the plasma-pause (the boundary of plasma which co-rotates with the earth, at about four earth radii).

An object immersed in a plasma absorbs particles from the plasma. In the magnetosphere, electrons are moving much faster than ions. Therefore, more electrons than ions will strike the probe, and it will acquire a net negative charge. However, as the negative charge builds up, it tends to de-

flect the oncoming electrons, and an equilibrium is reached when the object is negative enough to repel the proper flux of electrons to balance the positive and negative currents to the surface.

When parts of spacecraft surfaces are insulators (such as glass solar-cell covers), different portions will float at different potentials, depending on surface properties and solar aspects. At boundaries or sharp corners, the large gradients lead to possible discharge. The discharges create electromagnetic interference which may induce, by radiation or conduction, unwanted pulses in insufficiently shielded spacecraft electronic systems. The objective of this model is to develop a capability to predict charging of the spacecraft and to analyze its effects.

7.2 Aircraft Stores (PGMs & RPVs)

The objective of creating a supplemental model for aircraft stores is to provide a capability to analytically determine the EM compatibility requirements between an aircraft and its stores, including precision guided munitions (PGMs) and remotely piloted vehicles (RPVs). Although most of the EMC problems can be handled by the Intrasystem EMC Analysis Program (IEMCAP) or by the other supplemental models for the IAP, some unique problems require additional analytic models pertaining to aircraft stores. Aircraft stores include any device intended for internal or external carriage or mounted on aircraft suspension and release equipment, whether or not the item is intended to be separated in flight from the aircraft. Examples include missiles, mines, guns, and electronic countermeasure equipment. The stores are released by mechanical, electromechanical, electronic, and electroexplosive devices (EEDs).

It is imperative that the aircraft and the aircraft stores and related suspension equipment coexist without unacceptable EM effects on the aerodynamic, structural, or functional characteristics under any conditions encountered by the aircraft. The combination of stores in operational environments demands that EM compatibility requirements be known. Engineering judgment must be supported through all phases by appropriate analytic tools that cover all possible combinations of aircraft used as carriers and aircraft stores to insure safe and compatible operations.

7.3 Electroexplosive Devices (EEDs) and Subsystems (EESs)

Electroexplosive devices (EEDs) are used extensively by the military services to initiate such weapon system functions as bomb release and detonation and separation of mechanical structures of aerospace vehicles. Although many EEDs in the Air Force inventory have large variation in operating firing characteristics, they can be grouped into four broad categories:

1. Exploding bridgewire (EBW) type,
2. Hot bridgewire type,
3. Carbon bridge type, and
4. Conductive mix ignition type.

A basic grouping of firing modes can be made: pin-to-pin (heating, the basic mode); pin-to-case; arc mode; dielectric mode; and nonlinear conducting mode. The overall EES includes the complete firing mode, from initiation of controls to firing of the EED.

Since such systems are used in weapon systems they have been prim subjects in consideration of the vulnerability of a system to EM radiation from external environments or from internal coupling of extraneous EM energy. When high-level extraneous energy is coupled into the EES or directly coupled to the EED, the device can detonate accidentally. Sources of this high-level

energy can include static electricity charges, lightning, and internal signals generated by C&E equipment and EM transients. The large variety of EEDs in use and those being designed for use in future weapon systems, stresses the need for an analytic capability to determine vulnerability and formulate preventative measures. This need is also exemplified by the complex EM environments both external and internal to modern weapon systems.